ENGINEERING HERITAGE VICTORIA

Nomination for Heritage Recognition

B-24 Liberator Aircraft

Prepared By: Chris Killick, Elias Tagas, Thanh Ho, Alan Hankins

May 2014

Cover Image

Liberator A72-176 in its hangar at Werribee in 2003 showing progress on restoration at that time. Considerable further restoration has been carried out in the last decade.

Image: B-24 Liberator Memorial Restoration Australia Inc

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Heritage Award Nomination Letter

The Administrator
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Name of work: B-24 Liberator Aircraft

This work is nominated for an award under the Engineering Heritage Recognition Program.

Location, including addresses and map grid reference if a fixed work:
Werribee Satellite Aerodrome (37^0 54' 29.37"S, 144^0 38' 44.85E)
At the corner of Geelong Road and Farm Road, Werribee.

Owner (name & address): B-24 Liberator Memorial Restoration Australia Inc.
Post Office Box 156, Werribee, Victoria 3030.
Approval for the heritage recognition and ceremony has been obtained from the owner. Refer Appendix 5.

Access to site: Site is accessed off Geelong Road. The site is open to the public during times advertised on the website.

Nominating Body: Engineering Heritage Victoria (EHV)

Nomination prepared by: Alan Hankins, Thanh Ho, Christopher Killick, and Elias Tagas as a Victorian University Engineering student Work Experience assignment, with mentoring by structural engineer Geoff Taplin and oversight by EHV committee Chair Owen Peake.

Owen Peake - HonFIEAust CPEng

Chair, Engineering Heritage Victoria

Date: 20 May 2014

1.0 Introduction

Australia is fortunate to have preserved an important piece of World War II history inside a hangar located at the Werribee Satellite Aerodrome in Victoria. The aerodrome was established by the RAAF as a training airfield and a satellite to the nearby Point Cook and Laverton airfields. Inside the hangar is one of the world's eighteen remaining B-24 Liberator heavy bomber aircraft. This one in particular, A72-176, is the last remaining B-24 aircraft that served in the Royal Australian Air Force (RAAF) during the war.

The B-24 Liberator was used by many Allied air forces during World War II as it was considered to have a more advanced design for its time. It had greater speed, greater range and a heavier bomb load than its principal counterpart, the Boeing B-17 Flying Fortress bomber. It was a breakthrough in aircraft technology making the B-24 the most produced military aircraft of World War II. Post World War II in Australia saw the B-24 fleet turned into scrap metal. Liberator A72-176 was fortunate to avoid this fate and instead was used as a functioning surveying aircraft. Eventually the Liberator was disposed of on March 23 1948 from East Sale Airfield. The fuselage was purchased by nearby resident Mr George Toye in 1948, however the wings and tail were scrapped before the plane was purchased [1] .

Formed in 1989, B-24 Liberator Memorial Restoration Australia Inc.[2] dedicated their time and energy into restoring the B-24 back to its former glory. The restoration group aims to restore the aircraft to a "live" condition; however there are no intentions of flying the aircraft. Restoring the B-24 Liberator also celebrates the memory of the meritorious actions and sacrifices of men and women who served in Liberators during the Second World War.

This nomination document has been prepared to gain recognition through the Engineers Australia Engineering Heritage Recognition Program. Being the only B-24 Liberator remaining in the Southern Hemisphere, the restoration of Liberator B-24 A72-176 is deemed to be a worthy nomination for the following reasons:

- It incorporated the Davis Wing, a breakthrough innovative aeronautical engineering design, and other advanced design principles.
- The B-24 Liberator played a significant part in World War II in the European, Pacific, Indian Chinese and other theatres.
- The restoration of the aircraft is a remarkable project which brings those with interest in the B-24 together in collaboration to create a memorial to serve Australia's freedom and democracy.
- It is considered to be rare as it is the last of its type in the Southern Hemisphere.

[1] The aircraft can be identified as Type: B-24M-10-CO Liberator, RAAF Serial Number A72-176.

[2] Current title and name of The Australia B-24 Liberator Restoration

2.0 Heritage Assessment

2.1 Basic Data

Item Name

B-24M, A72-176 Liberator Heavy Bomber Aircraft

Other/ Former Names

"The Flying Coffin" [3]
"The Flying Boxcar " [4]
"Flyin' Home" [5]

Location

Werribee Satellite Airfield (37^0 54' 29.37"S, 144^0 38' 44.85E)

Figure 1 - Werribee Satellite Airfield Location (Hangar is in the field)

Source: Google Earth

[3] Louis Zamperini, served as a Bombardier on a B-24 in 1942. He referred to the B-24 as "The Flying Coffin".

[4] Allan Chuck, "A Brief History of The 44th Bomb Group" refers to the nickname of the B-24 Liberator as the "Flying Boxcar".

[5] Stewart Udall, served as a waist gunner on a B-24 in 1944. He was based in Southern Italy; 15th Army AF, 454th Bombardment Group. His Liberator's nickname was "Flyin' Home".

Address

The Werribee Satellite Airfield is located at the corner of Geelong Road and Farm Road, Werribee

Suburb/ Nearest Town

Werribee

State

Victoria

Local Government Area

City of Wyndham, 45 Princess Highway, Werribee, Victoria

Owner

B-24 Liberator Memorial Restoration Australia Inc, PO Box 156, Werribee, Vic 3030

Current Use

Undergoing continuing restoration for museum display

Former Use

Royal Australian Air Force (RAAF) bomber during World War Two, Operations in the Pacific Theatre

Designer

Consolidated Aircraft Corporation, San Diego, California, USA. The aircraft incorporates the novel Davis Wing profile

Maker/ Builder

Consolidated Aircraft Corporation, San Diego, California, USA

Year Started

Type first manufactured 1941

This aircraft delivered to RAAF in January 1945, it carried Australian serial number A72-176

Year Completed

Ceased manufacturing in 1945

Physical Description

The B-24 Liberator is a long range heavy bomber, employing the unique Davis high lift aerofoil and hydraulically operated Fowler flaps. The wing is mounted high on the fuselage to accommodate its large bomb bay. A twin fin and rudder assembly was chosen for the tail as it provided the stability required for accurate bombing. The Liberator also featured a retractable tricycle undercarriage with the main wheels retracting outwards to rest exposed in the wing housings, while the nose wheel retracted up under the cockpit floor. The tricycle undercarriage made the aircraft sit level on the ground which made the bomb loading process relatively easy.

The fuselage was divided into five major compartments: the nose, nose wheel, flight deck, bomb bays, and the waist of the aircraft. Inside the large fuselage was a catwalk which ran from the flight deck to the rear of the bomb bay. With the exception of the nose compartment; it was possible to walk upright along the entire length of the fuselage [6].

B-24 Specifications [7]

Engines:	4 Pratt & Whitney R1830 Twin Wasps, 1200 HP each
Weights:	16 tons (35,840 pounds) empty, 31 tons (69,440) laden [8]
Wingspan:	110 feet
Height:	18 feet
Length:	68 feet
Bomb load:	4 tons - various mixes [9]
Armament:	10 Browning - 50 caliber heavy machine guns
True Air Speed:	290mph max, 215mph cruise
Ceiling:	28,000 feet laden
Range:	2,100 miles, 3,000 miles on auxiliary tanks
Crew:	2 pilots, engineer, navigator, bomb aimer, 2 radio operators, 4 turret gunners

General Information

First Flight:	29 December 1939
Number Produced:	18,482
Main Users:	USAAF, USN, USMC, RAF, RAAF, Indian AF, RCAF

Physical Condition

Restoration nearing completion to “live” condition, no flight

[6] RAAF No 7 O.T.U Tocumwal

[7] B-24 Liberator Restoration Australia

[8] Empty weights up to 38,000 pounds have been quoted and laden up to 72,000 pounds.

[9] In practice bomb weights up to 8 tons were carried.

Modifications and Dates

Year	Event	Notes
1989	Formation of restoration group	
1995	Arrival of airframe	
1996	Airframe clean-up	
1993	Arrival of wings at Werribee hangar	
	Restoration of wings	Due to be completed 2015
	Installation of wings	
1996 - 2013	Beginning of restoration of airframe, re-skinning	
	Completion of airframe restoration	
1995	Arrival of instrumentation panel and seats	
2001 – 2003	Restoration and installation of instrumentation panel and seats	
2003 - 2015	Flight Deck restoration	Expected completion 2015
	Arrival and restoration of mid-upper & nose turrets	
	Purchase of engines and propellers	
1997	Installation of engines and propellers	
	Arrival of tail fin	
1999	Restoration of tail fin	
1996	Restoration of cockpit canopy	
1996	Arrival of landing gear	
	Installation of landing gear.	

Historical Notes

B-24 Design

In 1938, the United States Army Aircorp (USAAC) approached Consolidated Aircraft Corporation (CAC) about producing the new Boeing B-17 Bomber under licence, to expand America's industrial capacity. Upon visiting the Boeing plant in Seattle, Consolidated president Reuben Fleet assessed the B-17 and decided that a more modern aircraft could be designed using existing technology [10]. Consolidated responded in January 1939 with a new bomber with the following requirements of 300 mph airspeed with a range of 3,000 miles and 35,000 ft. ceiling; this set of specifications called for a bomber with higher speed and ceiling, as well as a greater range than the B-17.

American aeronautical engineer Isaac M. Laddon was appointed as chief designer [11] and created a high-wing monoplane that featured a deep fuselage with large bomb-bays, retracting bomb-bay doors, and tricycle landing gear. His design featured four Pratt & Whitney R1830 twin Wasp engines, the aircraft also featured long wings to improve performance at high altitude and increase payload. In addition, the wings possessed other technological improvements such as laminated leading edges. Impressed with the design, the USAAC awarded Consolidated a contract to build a prototype on March 30, 1939.

Dubbed the XB-24, the prototype first flew on December 29, 1939. Pleased with the prototype's performance, the USAAC moved the B-24 into production the following year. A distinctive aircraft, the B-24 featured a twin tail and rudder assembly as well as flat, slab-sided fuselage. This latter characteristic earned it the name "Flying Boxcar" with many of its crews. The B-24 was fairly simple, and the fuel consumption was highly efficient, although the narrow interior due to the positioning of the bomb racks limited movement within the aircraft.

B-24 Variations

There were numerous variants of the B-24 Liberator. Below is a table outlining the different models produced over the years:

Model Number	Description/Modifications
Model 31	• Flying Boat proposal for USN utilising Davis Wing later used on B-24
Model 32	• Consolidated company designation
XB-24	• Prototype Model Designation; • single example produced; • fitted with Pratt &Whitney R-1830-33 radial piston engines of 1000 horsepower
YB-24	• Pre-production Models

[10] The Aviation History Online Museum – Consolidated B-24 Liberator (Updated October 2013)

[11] Hired by Consolidated 1927, was Consolidated's Chief Engineer (Consolidated Aircraft Corporation by K.Pescador)

Service TEST XB-24 Model	• Deleted leading edge slots; • de-icing boots; • 7 examples produced
B-24A	• Initial Production Model; • 30 examples produced
XB-24B	• Fitted with R-1830-41 turbo-supercharged radial piston engines of 1200 horsepower each; • improved top speed; • revised engine cowlings; • singe example converted from the XB-24
B-24C	• Converted from B-24A; • revised engine cowlings; • Emerson A-6 power turret in tail with 2 x 12.7mm machine guns; • Martin power turret in nose
B-24D	• First quantitative production model; • fitted with Pratt & Whitney R-1830-43 supercharged engines; • ventral gun station replaced with Bendix turret then Sperry ball turret; • later models sported cheek machine guns for improved forward defence; • 2696 examples produced
B-24E	• Development of the D-model with production by Ford Motor Company; • fitted with Pratt & Whitney R-1830-65 radial piston engines; • ventral gun station of early models; • 801 examples produced
XB-24F	• B-24D Conversion Prototype Model to test de-icers
B-24G	• Production by North American Aviation; • fitted with 3 x 12.7mm machine guns in nose; • Sperry ball turret in ventral positions; • 405 examples produced
B-24G-1	• Production by North American Aviation; • based on B-24H; • fitted with Emerson A-6 nose turret replacing earlier machine gun arrangement
B-24H	• Ford Motor Company development; • fitted with Emerson A-6 turret in nose; revised airframe and bombardier compartment; • revised vision from tail turret and dorsal turret; • staggered waist gunners; • 3100 examples produced
B-24J	• Based on B-24H model sans armament arrangement; • improved autopilot and bombsight; • 6678 examples produced

XB-24K	• Development of Ford Motor Company; • B-23 Dragon empennage fused to B-24D airframe; • single example converted as such
B-24L	• Lightened attempt; • sans ball turret; • 2 x 12.7mm machine gun arrangement in ventral gun position; • M-6A turret in tail; • 1667 examples produced
B-24M	• Based on the B-24L lightening effort; • lightened A-6B tail turret; • uncovered waist gunner ports; • revised windshield; • 2593 examples produced (last production B-24s)

B-24 Production

The initial production batch of B-24As was completed in 1941, with many being sold directly to the Royal Air Force (RAF) Britain, where the bomber was dubbed "Liberator". The RAF soon found that they were unsuitable for combat over Europe as they had insufficient defensive armament and lacked self-sealing fuel tanks. Due to the aircraft's heavy payload and long range, the British converted these aircraft for use in maritime patrols. Learning from these issues, Consolidated improved the design and the first major American production model was the B-24C which also included improved Pratt & Whitney engines.

In 1940, Consolidated again revised the aircraft and produced the B-24D. The first major variant of the Liberator, the B-24D quickly amassed orders for 2,738 aircraft. Overwhelming Consolidated production capabilities, the aircraft was also built under license by North American, Douglas, and Ford. The latter built a massive plant at Willow Run, Michigan that, at its peak (August 1944), was producing fourteen aircraft per day. Revised and improved several times throughout World War II, the final variant, the B-24M, ended production on May 31, 1945 [12].

In addition to its use as a bomber, the B-24 airframe was also the basis for the C-87 Liberator Express cargo plane and the PB4Y Privateer maritime patrol aircraft. Due to the B-24's range and payload capabilities, it was able to perform well in the maritime role; however the C-87 proved less successful as the aircraft had difficulty landing with heavy loads. As a result, it was phased out as the C-54 Skymaster became available.

By the end of the war, a stunning 18,482 aircraft where built, making them the most produced allied aircraft in the war. They were used by every allied service in every theatre. 2100 of these planes were served with the British, 1200 with the Canadians, 287 with the Australians, a few served in the Mediterranean Sea with the Africans, while the vast majority served with the American forces [13].

[12] Chen, 2011.

[13] Ibid.

Operational History of the B-24 Liberator World Wide

The Liberator first saw combat action with the RAF in 1941, however due to their unsuitability they were reassigned to RAF Coastal Command. Improved RAF Liberator IIs flew bombing missions in early 1942, launching from bases in the Middle East. With the Unite States entry into World War II, the B-24 began to see extensive combat service [14]. The first US bombing mission was a failed attack on Wake Island on June 6, 1942. Six days later, a small raid from Egypt was launched against the Ploesti oil fields in Romania.

As US bomber squadrons deployed, the B-24 became the standard American heavy bomber in the Pacific Theatre due to its longer range, while a mix of B-17 and B-24 units were sent to Europe. Operating over Europe, the B-24 became one of the principal aircraft employed in the Allies' Combined Bomber Offensive against Germany. Flying as part of the Eighth Air Force in England and the Ninth and Fifteenth Air Forces in the Mediterranean, B-24s repeatedly pounded targets across Axis-controlled Europe. On August 1, 1943, 178 B-24s launched a famous raid against Ploesti as part of Operation Tidal Wave [15].

Departing from bases in Africa, the B-24s struck the oil fields but lost 53 aircraft in the process. While many B-24s were hitting targets in Europe, others were playing a key role in winning the Battle of the Atlantic. Flying from bases in Britain and Iceland, VLR (Very Long Range) Liberators played a decisive role in closing the "air gap" in the middle of the Atlantic and defeating the German U-boat threat. During the war, B-24s were credited in the sinking of 72 U-boats. The aircraft also saw extensive maritime service in the Pacific where B-24s and its derivative, the PB4Y-1, wreaked havoc on Japanese shipping.

While a workhorse of the Allied bombing effort, the B-24 was not hugely popular with American air crews who preferred the more rugged B-17. Among the issues with the B-24 was its inability to sustain heavy damage and remain aloft. The wings in particular proved vulnerable to enemy fire and if hit in critical areas could give way completely. It was not uncommon to see a B-24 falling from the sky with its wings folded upwards like a butterfly. Also, the aircraft proved highly susceptible to fires as many of the fuel tanks were mounted in the upper parts of the fuselage. In addition, crews nicknamed the B-24 the "Flying Coffin" as it possessed only one exit which was located near the tail of the aircraft. This made it difficult to impossible for the flight crew to escape a crippled B-24 [16].

It was due to these issues and the emergence of the Boeing B-29 Superfortress in 1944, that the B-24 Liberator was retired as a bomber at the end of hostilities.

[14] Ibid.

[15] Ibid.

[16] Chen, 2011.

Operational History of the B-24 Liberator Australia

The Royal Australian Air Force (RAAF) B-24 Liberator Long Range Heavy Bombers were used in the South West Pacific Theatre during World War II. The aircraft first came into service in 1941 and into RAAF service in 1944 [17].

Figure 2 - RAAF Liberator Dropping Bombs during World War II

Source: *http://b24australia.org.au/history.html*

The Pacific phase of World War II started when the Japanese attacked Pearl Harbour in December 1941. The Japanese overran all major Pacific islands and were soon poised to invade Australia [18].

The Allied response featured two main campaigns; a thrust across the central Pacific, basically by the US Navy, from 1942 which progressively wrestled key islands away from the Japanese and a general push across the island chains on the south western rim of the Pacific. It commenced in 1942 with the advance of the Australian Force over the Kokoda Track in New Guinea and the landing of a US Force in the Solomons [19]. It continued through New Britain, along northern New Guinea, some small islands in the northern Netherlands East Indies (NEI) and to the Philippines in late 1944.

The two campaigns coalesced when Okinawa was invaded in April 1945. Both campaigns deliberately bypassed large enemy concentrations which then mostly withered on the vine with the bypassed NEI posing some serious problems. It was rich in oil and other resources which gave significant strategic support to the Japanese war effort [20]. Such places were therefore guarded by well-equipped military forces. Allied strategy called for denial of these resources to the enemy and the neutralisation of Japanese garrisons.

[17] Livingstone, 2005.
[18] Ibid.
[19] Livingstone, 2005.
[20] Ibid.

Figure 3 - RAAF Liberator in Flight

Source: *http://b24australia.org.au/history.html*

The most effective instruments in implementing the above strategy were the Allied submarine forces and the long range B-24 Liberator. The eastern half of the NEI was initially covered by the USAAF B-24s from New Guinea, northern Australia but in mid-1944, the RAAF B-24s progressively replaced the American aircraft, so that when the war ended in August 1945 the seven RAAF squadrons were the area's dominant long range bombing force, operating from bases in Northern Territory, Western Australia, Morotai (NEI) and Palawan (Philippines). From 1944, Royal Air Forces B-24s from Cocos Island and Burma covered the western regions of the NEI and parts of South East Asia.

All types of land targets were attacked including oil fields and refineries, military bases, power stations, harbours etc. however the airfields were most frequently hit to reduce the enemy's communications and power to strike back [21].

There was barely an airfield in the entire archipelago which did not eventually resemble a cratered section of the moon. Due to the changing priorities, the RAAF squadrons used far more low level attacks on shipping that the Americans had. The good results were a valuable supplement to the submarines' tallies.

A major departure from the blockade role started in early April 1945 when strong detachments from RAAF Nos 21 and 24 Squadrons moved to Morotai to prepare the ground for the invasion of Borneo. From then until the end of the war Morotai was the main base for those two squadrons which provided the main strike force and reconnaissance of the Australian landings at Tarakan, Balikpapan and Labuan [22].

From March 1945, RAAF No 200 Flight (equipped with 8 B-24s) engaged in clandestine operations like dropping commandos behind enemy lines. It was based in Leyburn Queensland and operated all over the South West Pacific Area. From April 1945, No 201 Flight (also with 2 B-24s) engaged in radio

[21] Ibid.

[22] Livingstone, 2005.

and radar counter measures, operating from its base in Darwin. No 102 Squadron was another special unit engaged in radio experimentation and was based in Queensland.

Virtually all of the RAAF foundation air and ground crews for Nos 21 and 24 squadrons were introduced to the B-24 in the US 5th Air Force Heavy Bomber Replacement training unit, either at Port Moresby, or later at Nadzab, in New Guinea. After their conversion, each crew completed about 10 combat missions on enemy targets, often in association with the Americans as mixed crews or mixed formations [23]. But most B-24 crews were trained at the RAAF No 7 Operational Training Unit (OTU) at Tocumwal NSW, a very significant unit covering an enormous area and with the establishment for 50 aircraft and 5,000 personnel at its peak in 1945.

A72-176 was used for high altitude meteorological surveys towards Antarctica after World War II.

Heritage Listings

National Trust of Australia, Registration Number.B6706

Note: Heritage Victoria has not registered this aircraft.

[23] Ibid.

2.2 Assessment of Significance

2.2.1 Historical Significance

Refer to section 2.1 Basic Data – Historical Notes

2.2.2 Historic Individuals or Association

The United States Army Air Corps (USAAC)

The United States Air Force became a separate military service on September 18, 1947, with the implementation of the National Security Act of 1947 [24]. The Act created the National Military Establishment, later renamed the United States Department of Defense, which was composed of three branches, the Army, Navy and Air Force. Prior to 1947, the responsibility for military aviation was divided between the Army (for land-based operations) and the Navy, (for sea-based operations). The Army created the first predecessor of the Air Force in 1907, which through a succession of changes of organisation, titles, and missions advanced toward eventual separation. The predecessor organisations leading up to today's United States Air Force are:

1. Aeronautical Division, Signal Corps August 1, 1907 – July 18, 1914
2. Aviation Section, Signal Corps July 18, 1914 – May 20, 1918
3. Division of Military Aeronautics (May 20, 1918 to May 24, 1918)
4. Air Service, U.S. Army (May 24, 1918 to July 2, 1926)
5. U.S. Army Air Corps (July 2, 1926 to June 20, 1941) and
6. U.S. Army Air Forces (June 20, 1941 to September 17, 1947)

In 1935 the USAAC issued a new specification requirement to develop a new multi-engine, long – range heavy bomber capable of exceeding top speeds of 300 mph, besting a range of 3,000 miles, maintaining a service ceiling of 35,000 feet and taking on an internal bombload minimum of 8,000lbs.

Consolidated Aircraft Corporation (1923 – 1993)

The Consolidated Aircraft Corporation was founded in 1923 by Maj. Reuben H. Fleet in Buffalo, NY, the result of the Gallaudet Aircraft Company's liquidation and Fleet's purchase of designs from the Dayton-Wright Company as the subsidiary was being closed by its parent corporation, General Motors. Consolidated was the largest single employer in the country, employing in excess of 45,000 people in San Diego at one time [25]. This impact on the community was profound and long lasting. Whole communities sprung up just to house the influx of workers and their families. The city's infrastructure benefitted from the huge increase in the tax base with dozens of new schools, street improvements and other city benefits. Consolidated contributions to the war

[24] The primary source for the history of the USAF prior to 1947 is *Winged Shield, Winged Sword: A History of the United States Air Force* Vol. I (1997).

[25] Katrina Pescador, 2008.

effort were immense; in the month of January 1944 the San Diego plant produced 328 B-24 Liberators, PBYs (Catalinas), PB2Ys (Coronado), an average of over ten planes a day.

In 1941 Reuben H. Fleet sold his 34.25% interest share in Consolidated for $10.9 million to Victor Emanuel the president of AVCO (Aviation Corporation) with the idea that Consolidated would merge with AVCO's Vultee subsidiary. In 1943 Consolidated merged with Vultee aircraft to form Consolidated – Vultee Aircraft (Convair) [26]. In 1999 Convair Aircraft Structures was sold to Mcdonald Douglas, Boeing (The Boeing Company).

Figure 4 - Consolidated Fort Worth assembly point. "Note the PB4Y-1 which is navalised Liberator is being assembled on the far assembly line.

Source: *http://www.worldwarphotos.info/gallery/usa/aircrafts-2-3/b-24/b-24-assembly-line-fort-worth-texas/*

Reuben Hollis Fleet (1887 - 1975)

Reuben Hollis Fleet was born on March 6th, 1887, in Montesano, Washington. He attended Culver Military Academy in 1906 and went on to form a real estate business and became the youngest member of the state legislature in 1915. Just days before the United States entered the First World War, Fleet volunteered for pilot training with the US Army Signal Corps Aviation Section on March 22nd in 1917, thus beginning his long career in aviation [27]. In 1919 Feet was reassigned to McCook field in Dayton, Ohio, at the US Army Flight Test Centre, where he made contact with US aircraft contractors and manufacturers.

Fleet left the Signal Corps as a Major in 1922. He turned down executive positions with Boeing and Curtiss before joining the Gallaudet Aircraft Cooperation as vice president and general manager till the company folded. Acquiring the assets and engineering talents of Gallaudet Aircraft Corporation and the Dayton – Wright Airplane Company, Fleet combined the two into a new firm Consolidated Aircraft Corporation on May 29 1923.

[26] Katrina Pescador, 2008.

[27] Ibid.

Fleet hired Isaac Machlin Laddon, who had been in charge of design of heavy aircraft at McCook Field. One of his first goals was to secure the contract to design a twin-engine night bomber for the Army. Teaming with Sikorsky, they failed to win the competition with their S-37 design. Consolidated then went on to a long line of successful designs and lucrative contracts for seaplanes for the Navy. Starting with their XPY-1 of 1928, the company's string of successes culminated in one of the most numerous and successful seaplanes, the Consolidated PBY Catalina [28]. [The RAAF also operated Catalinas as its primary Maritime Patrol aircraft during World War II].

Figure 4A - Reuben Hollis Fleet (1887 - 1975)

Source: "These We Honour", The International Hall of Fame, The San Diego Aerospace Museum, San Diego CA, 1984.

Exploiting Fleet's experience in Army flight training, Consolidated produced a popular military training aircraft, the PT-11 (Consolidated Model 21) primary/advanced trainer. Leading Consolidated, Fleet founded or acquired a number of subsidiaries, including Fleet Aircraft to market civilian designs, Tonawanda Products Corporation to supply components, and Hall-Aluminium Aircraft Corporation. Among the companies acquired by Fleet during this time was the Thomas-Morse Aircraft which was failing yet had outstanding contracts to deliver.

[28] Yenne, 2010.

Fleet selected San Diego, California to relocate Consolidated from Buffalo, New York, where winter weather restricted seaplane operations. The move occurred in 1935.

After Fleet elected to sell a majority of his shares in Consolidated to Vultee Aircraft in 1941 he continued on in the role of adviser and consultant for five more years. He also became a private consultant for Franklin D. Roosevelt [29].

Consolidated went on to become a key supplier of heavy bombers with the widely produced B-24 Liberator playing a key role in the Allied strategic bombing campaigns, and the Convair B-36 the world's largest piston engine bomber, filling a crucial gap in the Cold War years until jet-powered bombers became widely available.

In August 1946, Fleet and his sister, Lillian, bought a parcel of land in Montesano and donated it to the city for use as a park named in honour of their parents. The city subsequently renamed Second Street to Fleet Street in their honour [30].

Leaving Consolidated, Fleet divided his time between his landmark home in Point Loma, California, the "Spanish Castle", and his residence in Palm Springs, California. During this time Fleet founded the Institute of Aeronautical Sciences and served on the California State Highway Commission. In 1961 Fleet founded the San Diego Aerospace Museum. In 1965 Fleet was invested in the International Aerospace Hall of Fame, and in 1967, Fleet's son, Sandy founded the Fotomat Corporation. In the early 1970s, Fleet largely funded construction of The Bishop Centre for Performing Arts at Grays Harbor College in Aberdeen, Washington, in honour of E. K. "Ned" and Lillian Fleet Bishop. Lillian was Fleet's sister, and "Ned" Bishop, a logging tycoon in western Washington State, was an early investor in Consolidated Aircraft. The Bishops left their fortune to a foundation that funds operation of the Bishop Centre.

Fleet married Elizabeth Girton on April 29, 1908 and they settled in Montesano, Washington. They had two children, Phyllis Fleet and David Girton Fleet; David later became an executive with Consolidated and a real estate developer, creator of the upscale Fleetridge neighbourhood in San Diego. Fleet and Elizabeth were divorced in 1920. In 1931 he married Dorothy Mitchell, and they had three children, Preston "Sandy" Fleet, Dorothy Fleet, and Nancy Fleet. Preston Fleet went on to found the Fotomat Corporation. Fleet and Dorothy were divorced in 1944. He married Eva May VanDenburgh in 1947. Fleet died in San Diego, California on October 29, 1975 at age 88 from injuries related to a fall.

David R. Davis (1894 – 1972)

David Davis was the Co-founder of Davis-Douglas Company; He was a freelance aeronautical engineer and developed the wing platform known as the Davis Wing used on the Consolidated B-24 Liberator. There is little information available on the life of David R. Davies.

[29] Ibid.

[30] Ibid.

Figure 5 – David R Davis

Source: San Diego Air and Space Museum Archive

Pratt & Whitney (1925 till Present)

Pratt & Whitney is a United States based aerospace manufacturer; it is now a subsidiary of United Technologies Corporation (UTC) [31]. Pratt & Whitney's aircraft engines are widely used in both civil and military aviation, Pratt & Whitney's R1830 (Twin Wasp) engines were used in the Consolidated B-24 Liberator.

The Twin Wasp was first produced 1932 and ceased production in 1951. It is a two-row, 14-cylinder, air-cooled radial design. It displaced 1,830 cubic inches (30.0 L) and its bore and stroke were both 5.5 in (140 mm), it delivered up to 1,350 horse power, up to 2,400 to 2,700 rev/min and weighed 1,620 pounds [32]. From their use in two of the most-produced aircraft ever built, the B-24 bomber and DC-3 transport, more than 173,618 R1830 engines were built; this is partly due to the urgency of WW2. Appendix 3 – shows details of the Pratt and Whitney Twin Wasp Engine.

During the 1930s, Pratt & Whitney were producers of five basic types of engines [33]:

- The single-row Wasp
- The single-row Wasp Junior
- The single-row Hornet
- The double-row Twin Wasp
- The double-row Twin Wasp Junior

The B-24 Liberator made use of four Twin Wasp Engines (model number S1C3-G). Components of the Pratt & Whitney Twin Wasp Engine consist of the cylinders, pistons, connecting rods, crankshaft, crankcase, valve gear, induction system, ignition, lubrication, reduction gear and accessory drives.

[31] Pratt & Whitney - A United Technologies Company.

[32] Pratt & Whitney R1830 – Maintenance Manual (Part No. 118610) Revised July, 1950.

[33] The Aviation History On-Line Museum, 2013.

The following table shows technical details of the S1C3-G Twin Wasp engine:

	"Twin Wasp" Series C
Model	S1C3-G
Number of Cylinders	14
Bore	139.5 m/m
Stroke	139.5 m/m
Capacity	30 Litres
Compression Ratio	6.7/1
Rotation	-
Gear Ratio	0.666, 0.500 or 0.5625
Diameter	1218 m/m
Length	1516 m/m
Weight	645kg for 0.666 gear 654kg for 0.500 gear 658kg for 0.5625 gear
Take-off Power	1050 hp at 2700 rpm
International Rating	1050 hp at 2550 rpm at 2285 m
Maximum Power	-

In Australia, the Twin Wasp Engine was license-built during World War II in Lidcombe, NSW, by the Commonwealth Aircraft Corporation (CAC). In 1940, the factory in Lidcombe had to quickly acquire the proper tools to prepare for the arrival of engines from Bristol Taurus in the UK in order to construct the Twin Wasps. The Ford Motor Company also started a large factory in Rocklea, Queensland to fix and maintain Twin Wasp Engines as well as additional engines from the Royal Australian Air Force and the United States Army Air Force [34].

In the United States, the Pratt & Whitney Twin Wasp Engines were produced by companies such as Ford and the Buick and Chevrolet Divisions of General Motors [35].

[34] Museum Victoria.

[35] Ibid.

Leonard S Hobbs (1896 – 1977)

Leonard Hobbs was an aeronautical engineer who started in 1920 with the Army Air Service at McCook Field in Dayton, Ohio and later worked for Stromberg Motor Devices Corporation [36]. He developed the first float-type carburettor for aircraft engines that was capable of providing normal operation during inverted flight. In 1927 he became a research engineer at the Pratt & Whitney Aircraft Company and by 1944 was vice president of engineering for parent company United Aircraft Corporation. He won the prestigious 1952 Collier Trophy for "designing and producing the P&W J57 turbojet engine" [37]. In 1956 he was elected Vice Chairman of United Aircraft, retiring in 1958 but remaining on the company's board of directors until 1968.

He was the author of *The Wright Brothers' Engines and Their Design*, published in 1971 by the Smithsonian Institution Press as part of its Smithsonian Annals of Flight series [38].

B-24 Liberator Memorial Fund (1988 till present, with subsequent name changes)

In 1988 some members of previous RAAF B-24 squadrons met, chaired by Wing Commander R.A. Dunne, D.F.C., R.A.A.F. (Retired), ex-commanding officer of No. 23 (Liberator) Squadron. The meeting examined the possibility of getting a B-24 Liberator on public display.

That meeting unanimously resolved to form the B-24 Liberator Memorial Fund with a foundation committee consisting of Bob Butler (Chairman), Eric Clark and Terry Lane, together with ex-officio members representing the R.A.A.F., The Australian War Memorial, and (later) the National Trust of Australia (Victoria).

The Committee first met in January 1989 to formulate plans, searching for aircraft or parts of them, from which a display could be assembled.

In December 1989 the Fund was formally incorporated as a non-profit Association under the model rules of the Victorian Associations Incorporation Act 1981, with the title “B-24 Liberator Memorial Fund Incorporated”.

At the Annual General Meeting in 1997, in recognition that the aircraft restoration was in fact proceeding, the word "Restoration" was added to more adequately describe the Fund's purpose which is registered as:

"To do all that is necessary to acquire and restore a B-24 Liberator and associated aircraft and artefacts, as a memorial to all those who served with Liberators during WW2, for display in an accredited museum as part of the national collection." [39]

[36] Hobbs, 1971.

[37] Ibid.

[38] Ibid.

[39] The B-24 Liberator Australian Restoration Fund proposed Mission Statement.

Vern F Roberts

Vern F Roberts was born in 1924, and was summoned for military service at the age of 18 and in 1942 attended basic training in Adelaide after joining the RAAF. At the completion of the training, he became a Flight Rigger and was called on his first training post at East Sale, Gippsland, Victoria for 8 months working on projects such as the Lockheed Hudson aircraft and Airspeed Oxfords. After this, Vern was posted to the Tocumwal RAAF Operational Training Unit, where he became part of the B-24 Liberator Squadron from then until the conclusion of World War II [40].

The next 18 months after this saw the formation of more Liberator Squadrons and eventually in June/July 1944, Vern's Squadron (number 24) was moved to the Northern Territory. He took part in bombing raids and often flew out for periods as long as 15 hours at a time. December 1944 marked his travel to Darwin where he boarded two Liberty Ships heading towards Morotai to carry out additional raids on Borneo and its surrounding islands.

Vern returned home for Christmas when World War II ended in 1945. He resumed his civilian life where he left off in 1942 when he joined the RAAF. In 1996, Vern became a part of the rebuilding of the B-24 Liberator Bomber. He was one of the many generous volunteers working on one of the world's biggest aircraft restoration projects going on at the time [41].

John Temby

John Temby (born in July 1925, Melbourne Australia) enlisted in the Air Training Corps, in which his brother was an instructor. After eighteen months training as a cadet John Temby was called up on the 13th of August 1943 into service, just two weeks after his 18th birthday where John was posted to the initial training school at Somers. His sister was a member of the Women's Auxiliary Australian Air Force (WAAF) who was working there eighteen months before John. While attending Somers, John was selected for pilot training and was posted to No. 11 Elementary Flying Training School at Benalla where he learnt to fly Tiger Moths. Upon completion of the course John was posted to number No. 1 Service Flying Training School at Point Cook where he trained in Airspeed Oxfords [42]. The course involved additional flying time, navigating and high – low bombing on the range west of Werribee. John had learnt wireless navigation for ultimate postings to such aircraft as Beaufighters and Mosquitos at No.2 Air Observation School at Mt Gambier. After several months at No. 2 School John was transferred to No.7 Operational Training Unit at Tocumwal where he was trained to fly the B-24 Liberator. The Liberator aircraft was a revelation according to John, "it was very friendly to fly and had no vices and, for the pilots it was very comfortable".

John's posting ended around the same time Japan surrendered in August 1945. John returned to civilian life where he was given a cadetship to the City Engineers at Heidelberg where he learnt civil engineering on the job whilst attending night classes to study the diploma. John eventually became

[40] B-24 Liberator Memorial Restoration Australia Inc, History, 2012.

[41] B-24 Liberator Memorial Restoration Australia Inc, 2012.

[42] B-24 Liberator Restoration Australia Inc, 2012.

Design and Contracts Engineer and was, in 1959, approached by a Sydney consultant with an offer to open, and manage, the Victorian branch of his practice; he accepted this offer. In 1985 the Sydney and Melbourne practices were separated and he became Managing Director of the new practice. John held this position until 2000 [43]. He then accepted a request from the Victorian Urban and Regional Land Corporation to become its Construction Manager; the position he held until he retired in 2008.

In 1992 John was fascinated, whilst listening to Ian McNamara's programme on ABC radio one Sunday morning, that Bob Butler - whom John had known in the ATC - was leading a group who were starting to restore a B-24 Liberator as a memorial to all who had served with these aircraft during the war. Investigation of this report led John to Werribee where he has been a worker on the aircraft to this day. He works three days a week on the project and is thrilled to see it nearing completion [44].

2.2.3 Creative or Technical Achievement

The Davis Wing

The B-24 liberator acquired a unique wing design known as the Davis Wing, which was designed by David R. Davis. This particular type of wing has a high aspect ratio design [45], offering low drag characteristics at a low angle of attack. The Davis wing alone enabled the B-24 Liberator to carry a greater bomb load, fly higher altitudes, fly a longer range and have superior cruise speed than other aircraft at the time such as the Boeing B-17.

Davis was a freelance Aeronautical engineer who had designed the wing by designing it in reverse, with a low drag teardrop shape and modified it as required to provide lift. Compared to other wing designs during its era, the Davis wing was thick, acquired a short chord and had a high aspect ratio profile.

Davis approached Consolidated Aircraft President Reuben H. Fleet. At this time, Davis claimed that his new wing design would offer lower drag than other wing designs. He also claimed that the design would offer considerable lift at small angle of attack, the thickness of the wing would allow for extra fuel storage giving the plane a longer range and that the engines could be embedded into the wings which was not a common practice at that time.

The main aim was to convince Consolidated Aircrafts to licence his wing design on the flying boat. At the time the flying boat required the nose to pull up for take-off and landing. This limited the plane due to the way it floated on water. Davis's wing design had the ability to lift at low angles of attack thus reducing the need to pull up the nose for take-off and landing.

[43] B-24 Liberator Restoration Australia Inc, 2012.

[44] Ibid.

[45] High aspect ratio is essentially the ratio of its length to its breadth. A high aspect ratio indicates long, narrow wings, whereas a low aspect ratio indicates short stubby wings.

Reuben H. Fleet and chief engineer Isaac M. Laddon were not completely convinced with the design and turned down Davis' offer. A couple of days later Isaac had a change of heart and convinced Reuben H. Fleet to pay for the wing tunnel test and the construction of a model of the Davis wing for testing. They specifically wanted to compare the Davis wing against their own design which they believed was the leading edge in wing design.

The modelled Davis wing was placed into the wind tunnel for testing. The results were so unbelievable that California University of Technology were asked to recalibrate their tunnel and redo completed tests. Once again the results were outstanding and to their disbelief the tunnel was recalibrated and tests re-run for a third time [46]. The wing tunnel results had indicated that the Davis wing delivered everything it claimed. It was suggested that it may be a case of wind tunnel fluke, which is when the wing performs well under the conditions of the wind tunnel however not so well in practise. Reuben had to make a decision whether to adopt the wing design or not. The wing performed well in the wind tunnel however there was uncertainty if the wing would perform as well in practice. After extensive thought Reuben H. Fleet decided to use the wing on Consolidated's new twin engine flying boat design, Model 31.

In May 1939, Model 31 was complete and taken for its first flight. The wing performed everything the wind tunnel and Davis claimed. At this point Consolidated was on a secret project, constructing the B-24 Liberator bomber. After the test flight of the Model 31 flying boat, the Davis wing was selected for the B-24 bomber. Every large Consolidated design, including the B-32 Dominator would adopt the same basic wing design from that point onwards.

Even though the wing performed well in lift and speed, it became unstable when committed to heavier loadings. From being pleasant to fly, the Liberator then became tricky to fly in high altitudes and in unfavourable weather. It was also found that the wing had become sensitive to ice formation distorting the aerofoil section, causing loss of lift. Unpleasant experiences with Liberators in heavy icing conditions led to many pilots making the comment that ..."the Davis wing won't hold enough ice to chill your drink" [47].

As the war ended so did the use of the Davis wing. It was only in the immediate post-war period that it became generally known that the high speed drag was strongly associated with thick wing profiles due to wave drag. As aircraft speeds of all types increased, the Davis wing's low-speed drag could not make up for its higher high-speed drag and so its use effectively ended.

The Fowler flap

Designed by Harlan D. Fowler in 1924, the Fowler Flap is still being widely utilised in modern aircraft designs to date. It was first tested in 1932 by Fred Weick and then later used as a 1935 prototype on the Martin 146 aircraft and on the 1937 Lockheed Electra [48].

[46] Tests were also carried out in another laboratory which confirmed the Caltech results.

[47] Modifications reduced icing problems as the war progressed.

[48] Lockheed Model 10 Electra, Wikipedia Foundation Inc, 2013.

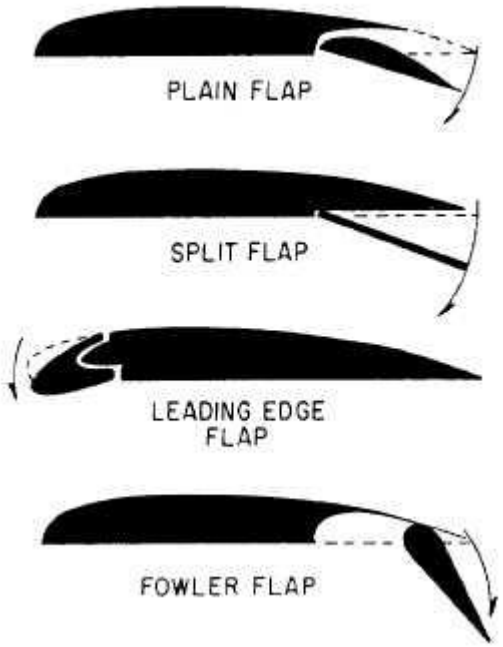


Figure 6 - Comparison between different flap designs

Source: Integrated Publishing, Houston, Texas, http://navyaviation.tpub.com

The Fowler flap's role is vital in assisting to provide high-lift for take-off and to lower stall speeds upon landing for the B-24 Liberator [49]. http://science.howstuffworks.com/consolidated-b-24-liberator.htm Not only this, but with Fowler flaps, sliding back and down the trailing edge of the Davis wing, it allows for the wing area to have suitable low speed performance when necessary [50]. They slide out from tracks under the wing to make a larger wing area and a decrease in wing loading. More lift to the plane is achieved at low flap settings before proceeding to full flaps.

The Fowler flap has a metal skin which covers around sixty percent of the Davis Wing's trailing edge [51]. It has an area of approximately 13.4 square metres, with a downward angle of 40 degrees. Each individual flap is reinforced by roller carriages which consist of five tracks. Four of these tracks are attached to the centre of the wing and the last is attached to the outer panel of the wing. They are an I-beam shape made of steel which are bolted onto a tubular planar truss. The front parts of the truss consist of clevises joined to lugs that go through the wing's spar via its flanges in order to attach to chord members. The Fowler flap controls include a cable system activated by a hydraulic cylinder with energy sources from the main hydraulic system's pressure [52].

[49] The Editors of Publications International, Ltd., 2014.

[50] Larry Jewell.

[51] Dave Unwin & The Collings Foundation, 2013.

[52] Famme, 1945.

2.2.4 Research Potential

The Liberator has been extensively researched and documented. No areas of further research became apparent during the writing of this nomination.

2.2.5 Social

The Liberator story is not as well known by the Australian public as some other aspects of World War II. However the Liberator was a workhorse which helped turn the tide of war and deserves greater recognition nationally and internationally. It also contains significant engineering aspects which should be better recognised by the engineering profession, particularly the use of the Davis wing. Socially the B-24 Liberator is an Australian Icon and it should be better recognised in Australian history.

2.2.6 Rarity

The A72-176 is the only remaining Liberator in Australia and the only remaining ex-RAAF Liberator.

Throughout the world, eighteen Liberators are restored to varying levels of condition which include 2 airworthy, 2 under restoration (including A72-176) and 3 partial airframes on display. There are also two wrecks in storage.

2.2.7 Representativeness

During the course of World War II, Consolidated's B-24 Liberator wasn't the only Tactical Heavy Bomber used. A total of 18 other bombers were used.

The main Aircraft associated with the Consolidated B-24 Liberator are as follows:

Boeing B-17, Flying Fortress

The B-17, arguably World War II's most famous heavy bomber, first flew on July 28, 1935, before a crowd of reporters eager to see Boeing's new bomber take wing. It was dubbed the "Flying Fortress" by the members of the press in attendance because of its (at least for the time) heavy defensive armament. The prototype crashed in October, but because of its impressive speed and handling the US Army Air Corps (USAAC) decided to continue testing anyway. They ordered 13 YB-17s for further evaluation, a decision that would prove momentous in years to come [53].

[53] The Doublestar Group, 2013.

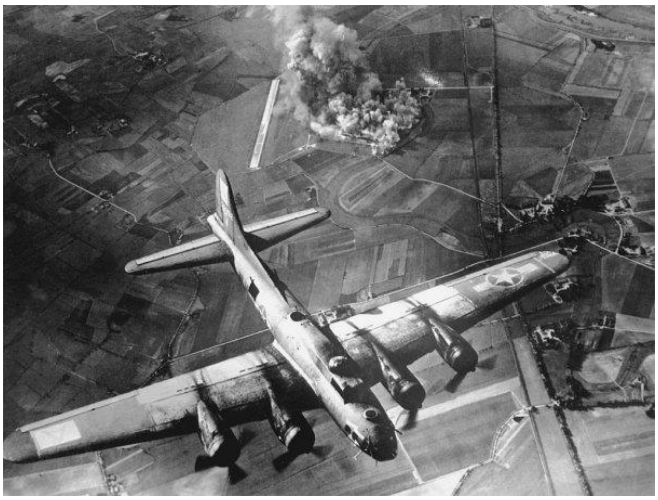


Figure 7 - An American B-17 bomber has the Third Reich in its sights during a mission over Germany during World War II.

Source: Army Air Corps

The YB-17 had five machine guns, room for 4,800 pounds of bombs and a crew of nine. It had electrically retractable landing gear. After testing the YB-17, an improved prototype, the Y1B-17, was built with Wright Cyclone radial engines. Twelve were delivered to the USAAC's 2nd Bombardment Group for trials. One of these was soon equipped with new Moss/General Electric turbochargers that became standard on all future Flying Fortresses. The first production order was for 39 B-17Bs with turbo-charged engines, and as soon as these were under production another order for the B-17C was placed, with seven machine guns instead of the original five.

The RAF received their first B-17Cs in 1941, and were soon conducting daylight raids over Germany. The defensive armament soon proved inadequate, and the B-17's altitude was little defence against the German fighters. Orders for the B-17D were soon placed with self-sealing fuel tanks and more armour because of lessons learned in bombing missions over Europe. The B-17E and B-17F soon followed with a larger tail. The B-17F was the first to serve with the USAAF 8th Air Force [54]. After suffering staggering losses in late 1943, analysis proved head-on attacks by enemy fighters were a distinct problem. The final major version, theB-17G, added a chin turret with dual machineguns. This gave the B-17 a defensive armament of 13 guns.

After the war, several dozen B-17s lived on as fire-bombers and aerial surveyors until the last one was retired in the 1970s. Today, a few B-17s have been restored to their wartime splendour. Eleven are currently flying in the United States, one in the UK and another one in France.

Nicknames: *Fort; The Flying Coffin* (Nazi propaganda nickname)

Specifications (B-17G):

Engines: Four 1,200-hp Wright R-1820-97 Cyclone turbocharged radial piston engines
Weight: Empty 36,135 lbs., Max Take-off 65,500 lbs.

[54] The Doublestar Group, 2013.

Wing Span: 103ft. 9in.
Length: 74ft. 4in.
Height: 19ft. 1in.
Performance:
Maximum Speed at 25,000 ft: 287 mph
Cruising Speed: 182 mph
Ceiling: 35,800 ft.
Range: 2,000 miles with 6,000 lb. bomb load
Armament:
13 12.7-mm (0.5-inch) machine guns
Up to 17,600 pounds of bombs

Number Built: 12,800+

Number Still Airworthy: 13

Avro Lancaster

Entering service at the beginning of 1942, the Lancaster's design grew out of a failed predecessor, the Avro Manchester. While its airframe offered a stable platform for heavy bombing assignments, the Manchester's twin engine design was inadequate to the task. By upgrading to four Rolls-Royce Merlin engines, the resulting aircraft met the nation's needs and 7,366 Avro Lancasters were built during the war, the most of any British bomber. Armament included eight to ten Browning machine guns for fighter defence (depending on model variant) mounted in the nose, upper dorsal turret and the tail [55].

Experience with a variety of bomb loads eventually led to adoption of the 'Grand Slam' 22,000-pound bomb, the largest carried by any aircraft in the war. For the dam-busting strike in May 1943, the Lancaster dropped British designer Barnes Wallis's 'bouncing bombs' which skipped on the surface before impact. Wartime Lancaster sorties totalled about 156,000 during which roughly 608,000 tons of ordnance were dropped on the enemy [56].

[55] Ibid.

[56] The Doublestar Group, 2013.

Figure 8 - Avro Lancaster owned and flown by the Canadian Warplane Heritage Museum

Source: *http://www.warbirdalley.com/lanc.htm*

As the war in Europe drew to a close, the Lancaster was readied for service against Japan as part of Bomber Command's 'Tiger Force', but the war's end put a halt to this plan. Apart from its primary bombing tasks, the versatile Lancaster was also used for maritime surveillance, photo reconnaissance missions and, later, as an engine test bed platform. The final airframe was delivered in February 1946, but the plane flew for many years in civilian guise and as a warplane when sold to other nations. A number of Lancasters were preserved and still can be viewed at museums, but only two still fly under their own power to air shows -- one in Canada and one in the UK [57].

The Avro Lancaster B1, known with affection as "G for George", has a remarkable history. "G for George" flew ninety operational missions over Germany and occupied Europe during the height of the bomber offensive. From the time it was built in 1942 until its retirement from active service in 1944, the bomber was flown by No. 460 Squadron RAAF (when in Britain) [58].

The plane has always been one of the most popular exhibits at the Australian War Memorial. After undergoing extensive restoration at the Australian War Memorial's Treloar Conservation workshops, it went back on display in Anzac Hall in "Striking by night", a permanent exhibition featuring a dramatic sound and light show that re-creates a night bombing operation over Berlin in December 1943 [59]. Three German Messerschmitt fighter aircraft also feature in the display.

[57] Ibid.

[58] Australian War Memorial.

[59] Australian War Memorial.

Figure 9 – "G for George" a Lancaster aircraft belonging to No. 460 Squadron RAAF

Source: Australian War Memorial

Nicknames: *"Lanc"*

Specifications (Lancaster Mk I):

Engines: Four 1,460 hp Rolls-Royce Merlin XX V12 liquid cooled piston engines.
Weight: Empty 36,900 lbs, Maximum Takeoff 68,000 lbs.
Wingspan: 102 ft 0 in.
Length 69 ft 6 in.
Height: 20 ft 0 in.
Performance:
Maximum Speed at 12,000 ft: 287 mph
Service Ceiling: 24,500 ft
Range with 14,000 pound load: 1,660 miles
Armament:
Two 0.303-inch (7.7mm) guns in nose, ventral and dorsal turrets.
Four 0.303-inch (7.7mm) guns in tail turret.
Fourteen 1,000 pound bombs.
Crew: 7

Number Built: 7,366

Number Still Airworthy: Two

The following table shows relevant aircraft types [60].

Name of Aircraft	Year Introduce	Year Retired	Operators	Manufacturer	Cost (AUD)	Length (m)	Top Speed
Avro Lancaster	1942	1963	United Kingdom, Canada and Australia	Avro	$92,010.35 in 1943	21.00	505 km/h
Avro Manchester	1940	1942	United Kingdom and Canada	Avro	N / A	21.00	426 km/h
Blohm & Voss BV 142	1940	1942	N / A	Blohm and Voss	N / A	20.00	375 km/h
Boeing B-17 Flying Fortess	1935	1968	United States, United Kingdom and Canada	Boeing	$262,101.00	22.00	462 km/h
Boeing B-29 Superfortress	1944	1960	United States	Boeing	$702,945.09	30.18	574 km/h
Consolidated B-24 Liberator	1941	1945	United States, Australia, Canada and United Kingdom	Consolidated	$327,314.40 In 1940	21.00	470 km/h
Consolidated B-32 Dominator	1944	1945	United States	Consolidated	N / A	25.03	575 km/h
Consolidated PB4Y-2 Privateer	1943	1958	United States	Consolidated	N / A	22.70	482 km/h
Farman	1935	1938	France	Farman	N /A	21.50	320

[60] Military Factory, 2014.

F.221-223				Aviation Works			km/h
Focke-Wulf Fw 200	1937	1944	Germany	Focke-Wulf	N /A	23.45	360 km/h
Handley Page Hailfax	1940	1945	United Kingdom, Canada, Australia and France	Handley Paige	N / A	21.82	454 km/h
Heinkel He 177	1942	1945	Germany	Heinkel Flugzeugwerke	N / A	22.00	565 km/h
Mitsubishi Ki-20	1931	1935	Japan and Germany	Mitsubishi	N / A	23.20	201 km/h
Petlyakov Pe-8	1936	1934	Soviet Union	Factory No. 124	N / A	23.20	443 km/h
Piaggio P.109	1942	1945	Itlay	Paiggo	N / A	22.30	430 km/h
Short Stirling	1940	1946	United Kingdom	Short Brothers	N / A	26.60	454 km/h
Tupolev TB-3	1939	1945	Soviet Union	Tupolev	N / A	24.40	212 km/h
Vickers Warwick	1942	N / A	United Kingdom, Poland and South Africa	Vickers-Armstrongs	N / A	22.00	361 km/h

2.2.8 Integrity/ Intactness

The restoration of a Liberator which served with the RAAF presented an immense challenge. This has been achieved with great success by B-24 Liberator Memorial Restoration Australia Inc.

The restoration of A72-176 has been done in such a way as to create a complete aircraft without destroying the heavily deteriorated fabric recovered. Whilst this means the aircraft will not be restored to airworthy condition, it will be complete including operating engine and will be able to taxi.

3.0 Statement of Significance [61]

Cultural

During the Second World War, seven squadrons and two special flights of the Royal Australian Air Force flew a total of nearly 300 Consolidated B-24 Liberators in defending Australia against Japanese aggressors. They were especially instrumental in deterring an invasion force of 50,000 Japanese troops assembled in Timor. Though more than 18,000 of these aircraft were built in the USA during the war, only eighteen remain world-wide today. A72-176 is the only survivor from the RAAF's wartime fleet, and the only one remaining in this country. On 15 August 2000 this aircraft was dedicated as a national memorial to those who maintained and flew the Liberator during the dark days of World War II. The actual ceremony and all that has gone into the aircraft's restoration was the subject of an episode of the ABC TV's Australian Story three days later. Even in its incomplete state, the aircraft itself has already become a focus for veteran reunions, and is still amazingly capable of stirring personal emotions - perhaps in laying ghosts to rest - amongst many of the older visitors to the Werribee restoration site.

Historical

The B-24 Liberator represents the ultimate strength of the heavy bomber capacity of the Royal Australian Air Force during World War II, which at the height of its development operated these aircraft in seven squadrons and two special flights during the war in the Pacific. It was the largest aircraft in service with the RAAF in wartime and is the only one remaining from a fleet of nearly 300. As such it is now an historic aircraft of national significance, an icon in the history of Australia's aviation heritage and development as well as a monument to our nation's military resolve to resist the might of a would-be invader.

Scientific

The B-24 represents a notable advance in the development of aviation technology in being the first practical application of the American, Davis-designed wing. Though the design of this long tapering low-drag, high aspect ratio structure was several years old at the time, the 1939 Liberator prototype became the first production aircraft to adopt the design, around which the rest of the aircraft was built. The new wing gave a much improved performance with fewer materials used in its construction, and thus less weight overall, compared with its contemporaries. In this respect it was regarded as the forerunner of the modern aeroplane in terms of longer slimmer wings, which eventually took on the swept-wing configuration of today's large passenger jets. It also pioneered the use of tricycle undercarriages on large four-engine aircraft which eventually became the stamp of modern aircraft design, as well as testing and deploying new radar developments as they became available. This particular B-24MR Liberator (R denoting its radar applications) is the only one of its kind left in the world. It therefore has some claim to international significance.

[61] Victorian Heritage Data Base – Statement of Significance

Social

Some 20,000 RAAF personnel serviced and flew these aircraft from Australian bases during the Second World War. Many more flew them as early volunteer members of Britain's Royal Air Force, not only in Bomber Command, but also in Coastal and Transport Commands. Australian veterans and others from overseas therefore spent a considerable part of their younger lives in association with this aircraft during World War II. Many gave their lives in the defence of this country, and in the liberation of Europe. Of the 287 RAAF Liberators on operations a total of 33 aircraft, or more than 10% of their numbers, were lost in the south-west Pacific theatre during the war, mostly as a result of enemy action. July 1945 was a particularly bad month, when 5 aircraft were lost together with 50 men. A further 170 aircrew also died in association with the other losses. As bad as it was, this total does not reflect the many other Australian airmen who gave their lives while flying B-24s in other theatres. For this reason the aircraft was dedicated as a national memorial to all these people on 15 August 2000, the 55th Anniversary of the end of the war in the Pacific.

4.0 Area of Significance

National and International

5.0 Interpretation Plan

5.1 General Approach

The strategy for interpretation of the Engineering Heritage Works is laid out in the latest version of the EHA's "Guide to the engineering Heritage Recognition Program" [62]. The interpretation will be by marking the works with an appropriate level of heritage marker; a public ceremony to unveil that marker and an interpretation panel which summaries the heritage and significant features of the works or the public.

This plan provides a summary of the proposals for design, content, location, manufacture and funding of the proposed interpretation.

5.1.1 Date For Event

The ceremony could be held on Sunday 13 July 2014. Note that discussions are ongoing with B-24 Liberator Memorial Restoration Australia Inc about the time and format of the ceremony.

5.1.2 The Interpretation Panel

The following will be incorporated into the design of the panel:

1. A title - "B-24 Liberator Restoration"
2. A Subtitle – "Restoring a Legendary Long Range Heavy Bomber"
3. Logos of Engineers Australia and B-24 Liberator Memorial Restoration Australia Inc.
4. A small scale representation of the EHA marker plate
5. The date and other details of the marking ceremony
6. A website reference to the availability of the full nomination on the EHA webpage
7. A QR code to the above reference
8. Text for main text panel should be 30 point
9. Minimum Text size should be 24 point
10. Historic photographs will be used to illustrate the panel, with brief captions for each photograph and source references to be used with each photograph

The interpretation panel will technically be constructed and erected as follows:

1. Size to be nominally 1200 mm wide by 600 mm high
2. The panel to be constructed of vinyl reflective film on aluminium plate with flanges per drawing at Appendix 3
3. The panel to be mounted on a steel free-standing frame as per Appendix 3 or modified to suit the circumstances
4. The EHA marker to be mounted below the interpretation panel as shown in Appendix 3

[62] The 2012 Version - Guide to the engineering Heritage Recognition Program.

The location of the interpretation panel has not yet been agreed with B-24 Liberator Memorial Restoration Australia Inc.; however it is likely to be placed inside the hangar containing the aircraft.

5.1.3 Design Process For The Panel Content

Graphic design will be carried out by Mr Richard Venus under contract to EHV.

The nomination will be reviewed during its development by the following parties:

1. the 10 members of the committee of the Engineering Heritage Victoria
2. The committee of the B-24 Liberator Memorial Restoration Australia Inc.
3. Mr Geoff Taplin, Mentor for the project.

The design of the interpretation panel will be developed to the initial concept stage as part of the nomination writing process. It will then be further developed to a draft panel status for submission to the Heritage Recognition Committee.

Manufacture will then be carried out by Advanced Group, Melbourne.

5.1.4 Funding

Funding for the interpretation panel is expected to be required as followed:

Item	Fund Source	Amount
Graphic Design (including purchase of photographic rights)	EHA National Board budget	$500
Manufacture of panel (Advanced Group)	EHV budget	$450
Manufacture of frame (Supplier Name)	To be resolved	$1000
Installation of panel stand and panel	B-24 Liberator Memorial Restoration Australia Inc	By volunteers
Supply from stock of EHA markers	EHA National Board budget	$300
	Total:	$2250

5.2 Possible Interpretation Themes for Interpretation Panel

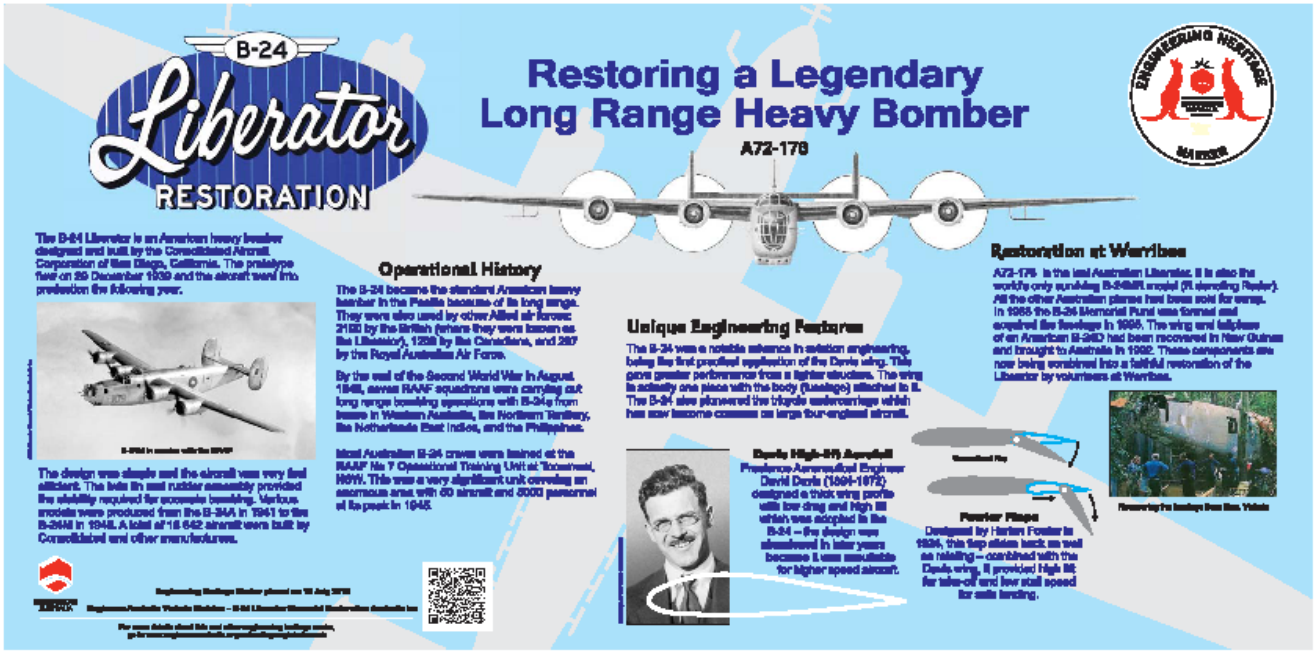
In accordance with good interpretation practice the contents of the panel should be divided into three or four themes for ease of understanding by the public.

The following subjects have been assessed as themes or sub-themes for the interpretation panel:

1. History of the B-24 Liberator
2. History of the restoration of A72-176
3. Engineering innovations in the Liberator
4. Individuals associated with Liberators

5.3 Preliminary Design of Interpretation Panel

Richard Venus has carried out the design of the interpretation panel. Design of the Interpretation Panel, Version 2 is shown below:



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Appendix 1- Images with Captions

IMAGE 1 : The A72-176 Liberator in the Werribee Hangar. Restoration in progress.

Source: B-24 Liberator Memorial Restoration Australia Inc.

IMAGE 2: Liberator 'A72-176' on display at the Werribee hangar. Wing restoration complete and now waiting the installation of the Pratt & Whitney Twin Wasp engines.

Source: Owen Peake, November 2013

IMAGE 3: Pratt & Whitney R-1830 Twin Wasp **e**ngine run 27 Oct 2013.

Source: Owen Peake, 2013

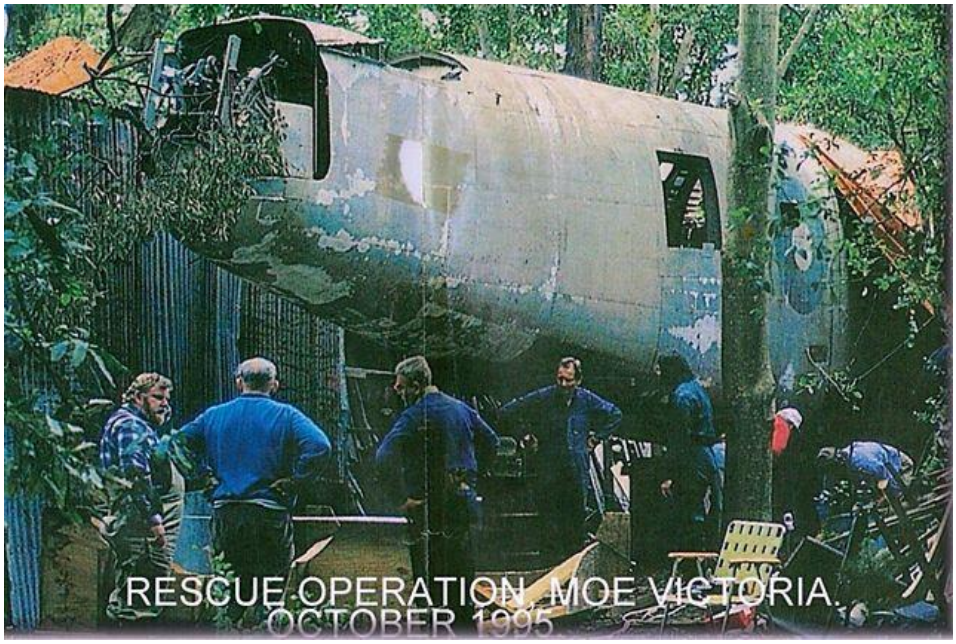


IMAGE 4: Liberator A72-176. Fuselage at Moe Oct 1995

Source: B-24 Liberator Memorial Restoration Australia Inc

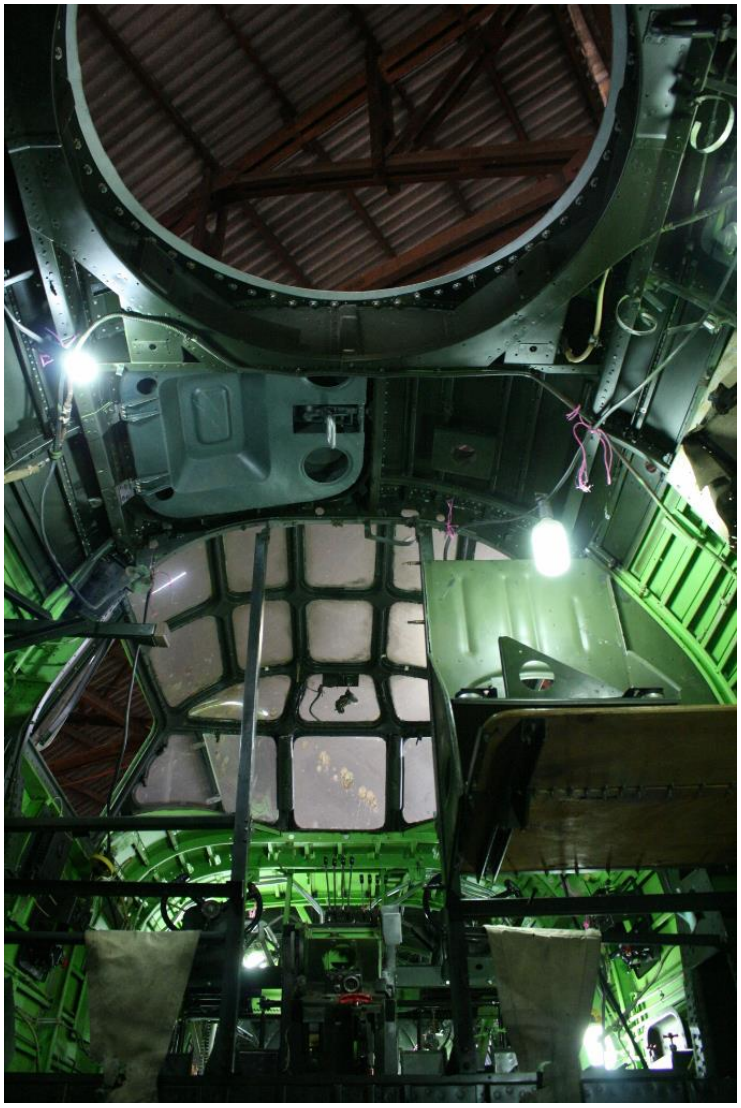


IMAGE 5: The cockpit area restored. Still waiting for the installation of the seats.

Source: Owen Peake, November 2013

IMAGE 6: B-24 Very Long Range Liberators at the Consolidated-Vultee Plant, Fort Worth, Texas
Source:
http://images.google.com/imgres?imgurl=http://afhra.maxwell.af.mil/photo_galleries/aaf_wwii_vol_vi/Photos/00910460_083.jpg&imgrefurl=http://afhra.maxwell.af.mil/photo_galleries/aaf_wwii_vol_vi/Captions/083_Peak_Production.htm&usg=__jvE1JktPD7POajd_52iaPs-xTHA=&h=665&w=860&sz=153&hl=en&start=43&um=1&tbnid=6UwsZqdnFaR26M:&tbnh=112&tbnw=145&prev=/images%3Fq%3DB-24%2Baf.mil%26start%3D40%26ndsp%3D20%26um%3D1%26hl%3Den%26safe%3Dactive%26sa%3DN [2014]

IMAGE 7: B-24 Liberator. "All American" Patrick Bunce
Source: RAAF photo acquired by B-24 Liberator Memorial Restoration Australia Inc

IMAGE 8: Liberator A72-176 on display in the Werribee hangar. At this stage the nose turret and engines have not been installed.

Source: B-24 Liberator Memorial Restoration Australia Inc

IMAGE 9: B-24 bombers under construction at Ford Motor Company's Willow Run Factory, circa 1941-1945

Source: United States Air Force http://ww2db.com/image.php?image_id=3376

IMAGE 10: A72-176 on display at Werribee. In the top left corner the mounts for the engines are installed in preparation for the R-1830 Twin Wasps

Source: Owen Peake, November 2013

IMAGE 11: A72-176 during its service in Tocumwal 1945.

Source: Royal Australian Air Force Photograph, acquired by B-24 Liberator Memorial Restoration Australia Inc

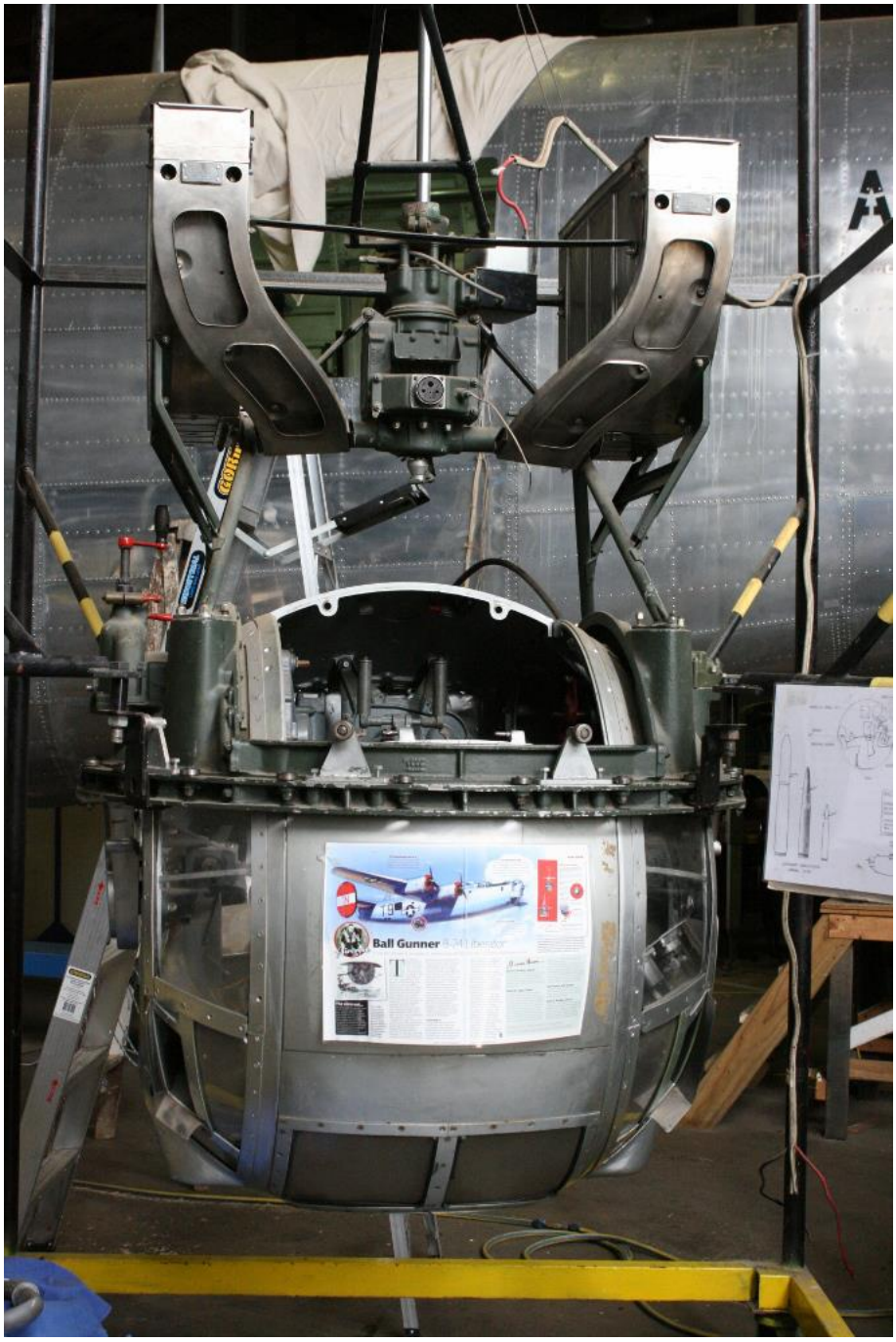


IMAGE 12: Restored ball turret**.**

Source: Owen Peake November 2013

IMAGE 13: Restored Ball Turret

Source: Owen Peake November 2013

IMAGE 14: The condition of the Liberator A72-176's cockpit upon arrival at the Werribee hangar

Source: Martin Edwards 1996

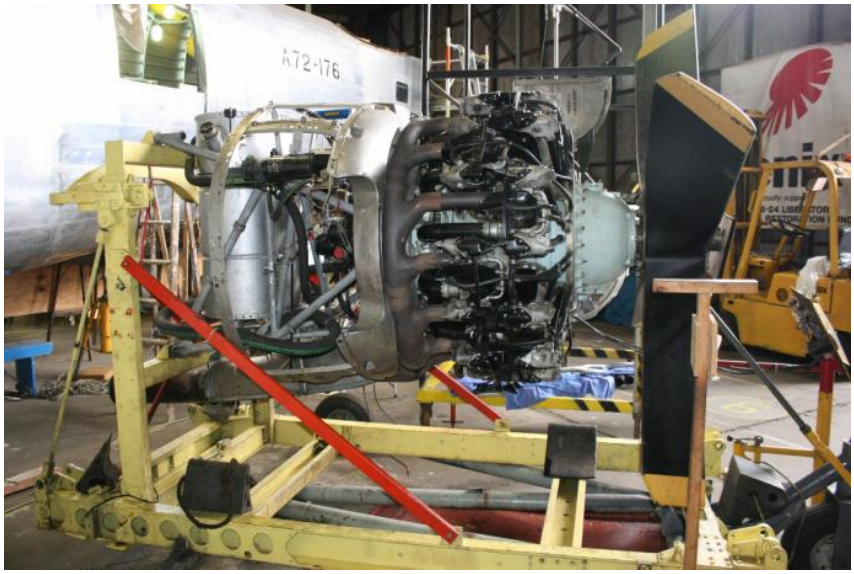


IMAGE 15: Pratt & Whitney Twin Wasp engine

Source: Owen Peake, November 2013

IMAGE 16: Nose restoration with nose turret installed.

Source: Owen Peake, November 2013

IMAGE 17: A view of the complete aircraft as at November 2013.

Source: Owen Peake, November 2013

IMAGE 18: A72-176 nose comparison from 1995 to 2013

Source: B-24 Liberator Memorial Restoration Australia Inc

IMAGE 19: The front of the Liberator A72-176 during removal and transportation from Moe to Werribee. The plane had to be split into two halves for transporting and safety.

Source: B-24 Liberator Memorial Restoration Australia Inc

IMAGE 20: A72-176 fuselage comparison inside views 1995 to 2013.

Source: Left: B-24 Liberator Memorial Restoration Australia Inc, Right: Owen Peake, November 2013

IMAGE 21: Liberator fuselage section. Dismantled into two parts for transportation purposes.

Source: B-24 Liberator Memorial Restoration Australia Inc

IMAGE 22: Liberator tail section before restoration

Source: B-24 Liberator Memorial Restoration Australia Inc

IMAGE 23: New undercarriage fitted.

Source: Owen Peake, November 2013

IMAGE 24: Restored and installed 50 calibre Browning waist-gun.

Source: Owen Peake, November 2013

IMAGE 25: Nose turret installed.

Source: B-24 Liberator Memorial Restoration Australia Inc

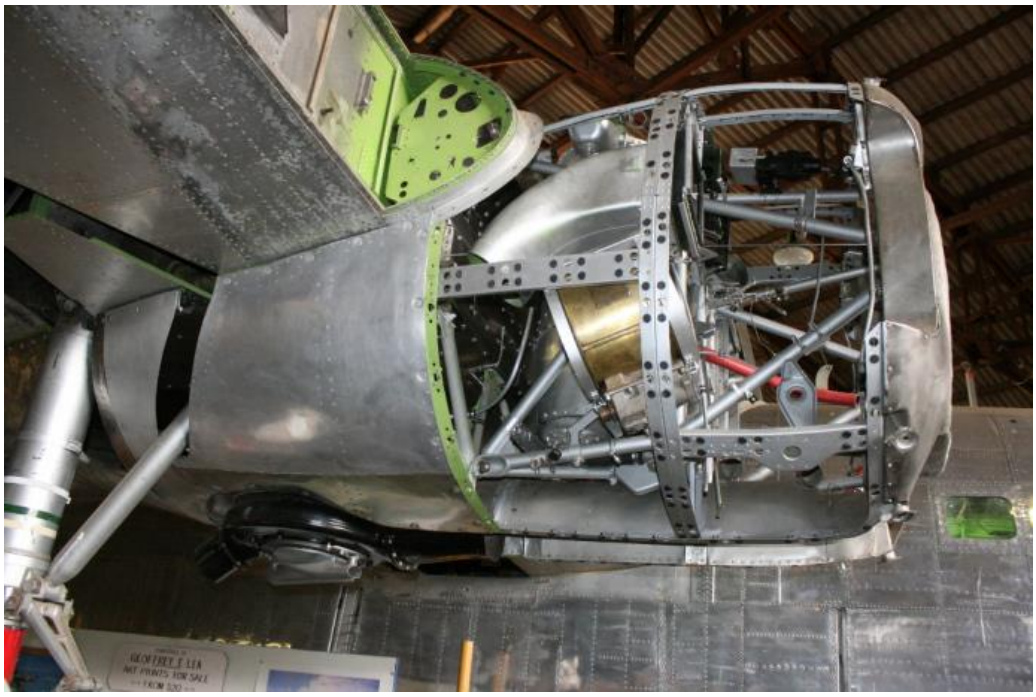


IMAGE 26: Engine housing installed

Source: Owen Peake, November 2013

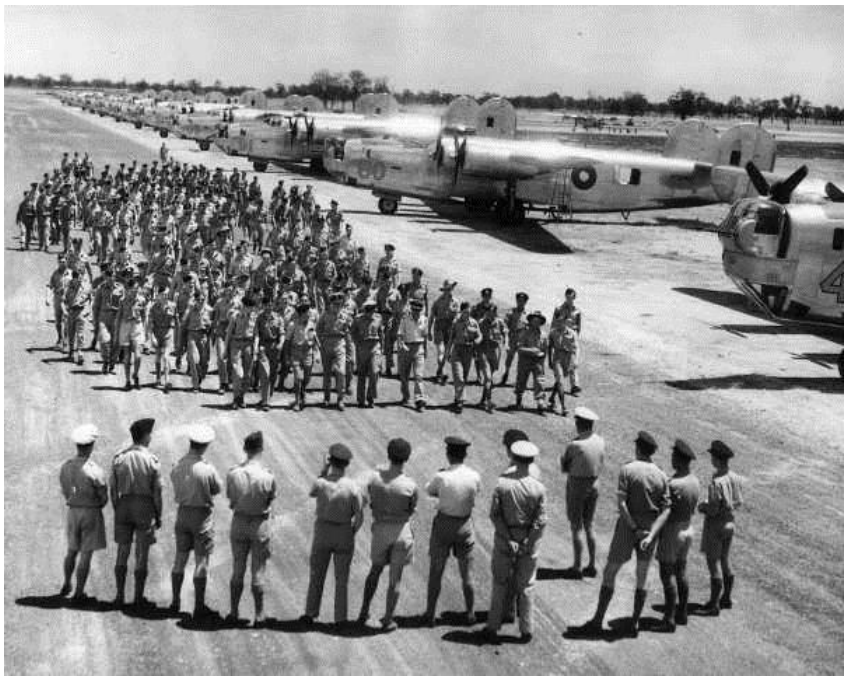


IMAGE 27: RAAF base Tocumwal Liberators and crew standing by

Source: RAAF photo acquired by B-24 Liberator Memorial Restoration Australia Inc

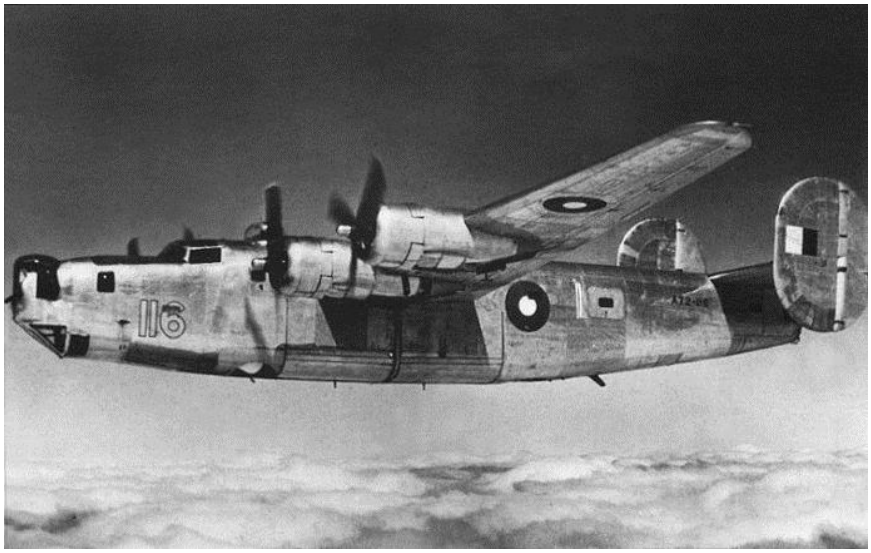


IMAGE 28: RAAF AS72-116 Liberator cruising at altitude

Source: RAAF photo acquired by B-24 Liberator Memorial Restoration Australia Inc

IMAGE 29: RAAF Liberator taxing at Tocumwal Air Base

Source: Tocumwal Historic Aerodrome Museum

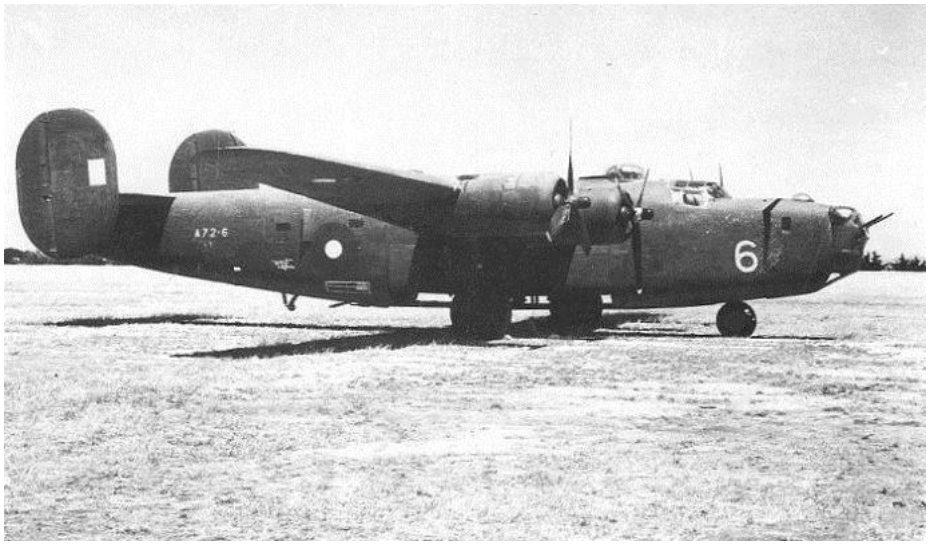


IMAGE 30: AS72-006 at RAAF Base Tocumwal

Source: Australian Deference Force

Appendix 2 - Pratt & Whitney R-1830 Aircraft Engine [63]

The Pratt & Whitney R-1830 Twin Wasp was an American aircraft engine widely used in the 1930s and 1940s. Produced by Pratt & Whitney, it was a two-row, 14-cylinder, air-cooled radial design. It displaced 1,830 cu in (30.0 L) and its bore and stroke measured 5.5 and 5.5 in (140 and 140 mm), respectively. A total of 173,618 R-1830 engines were built. An enlarged version with a slightly higher power rating was produced as the R-2000.

Specifications: (for R-1830-S1C-G)

Type: two-row, 14-cylinder, air-cooled radial
Manufacturer: Pratt & Whitney
First run: 1932
Number built: 173,618

General characteristics

Type: Fourteen-cylinder two-row supercharged air-cooled radial engine
Bore: 5.5 in (139.7 mm)
Stroke: 5.5 in (139.7 mm)
Displacement: 1,829.4 in³ (30 L)
Length: 59.06 in (1,500 mm)
Diameter: 48.03 in (1,220 mm)
Dry weight: 1,250 lb (567 kg)

Components

Valvetrain: Two overhead valves per cylinder
Supercharger: Single-speed General Electric centrifugal type supercharger, 7.15:1 reduction
Fuel system: Two-barrel Stromberg carburettor
Fuel type: 95-100 octane rating gasoline
Cooling system: Air-cooled
Reduction gear: Epicyclic gearing, 2:3

Performance

Power output:
- 1,200 hp (895 kW) at 2,700 rpm for takeoff
- 700 hp (522 kW) at 2,325 rpm cruise power at 13,120 ft (4,000 m)

Specific power: 0.66 hp/in³ (29.83 kW/L)
Compression ratio: 6.7:1
Specific fuel consumption: 0.49 lb/(hp•h) (295 g/(kW•h))
Power-to-weight ratio: 0.96 hp/lb (1.58 kW/kg)

Variants

R-1830-1 - 800 hp (597 kW)
R-1830-9 - 850 hp (634 kW), 950 hp (708 kW)
R-1830-11 - 800 hp (597 kW)
R-1830-13 - 600 hp (447 kW), 900 hp (671 kW), 950 hp (708 kW), 1,050 hp (783 kW)
R-1830-17 - 1,200 hp (895 kW)

[63] http://powerplants.warbirdsresourcegroup.org/unitedstates_powerplants_P-W_R-1830_Twin_Wasp.html

R-1830-21 - 1,200 hp (895 kW)
R-1830-25 - 1,100 hp (820 kW)
R-1830-33 - 1,200 hp (895 kW)
R-1830-35 - 1,200 hp (895 kW) Fitted with GE B-2 turbosupercharger
R-1830-41 - 1,200 hp (895 kW) Fitted with GE B-2 turbosupercharger
R-1830-43 - 1,200 hp (895 kW) Fitted in B-24 Liberators
R-1830-45 - 1,050 hp (783 kW)
R-1830-49 - 1,200 hp (895 kW)
R-1830-64 - 850 hp (634 kW), 900 hp (671 kW)
R-1830-65 - 1,200 hp (895 kW)
R-1830-66 - 1,000 hp (746 kW), 1,050 hp (783 kW), 1,200 hp (895 kW)
R-1830-72 - 1,050 hp (783 kW)
R-1830-82 - 1,200 hp (895 kW)
R-1830-86 - 1,200 hp (895 kW)
R-1830-88 - 1,200 hp (895 kW)
R-1830-90 - 1,200 hp (895 kW)
R-1830-90-B - 1,200 hp (895 kW)
R-1830-92 - 1,200 hp (895 kW)
R-1830-94 - 1,350 hp (1,007 kW)
R-1830-S1C3-G - 1,050 hp (783 kW), 1,200 hp (895 kW)
R-1830-S3C4 - 1,200 hp (895 kW)
R-1830-S3C4-G - 1,200 hp (895 kW)
R-1830-S6C3-G - 1,100 hp (820 kW)
R-1830-SC-G - 900 hp (671 kW)
R-1830-SC2-G - 900 hp (671 kW), 1,050 hp (783 kW)
R-1830-SC3-G - 1,065 hp (749 kW) Swedish unit built under license by SFA company for Finnish VL Myrsky II

Appendix 3 – Jane's All The World's Aircraft 1939, Pratt & Whitney Twin Wasp Series [64]

CRANKCASE.—In six sections. Power sections machined together from aluminium forgings. Nose section houses reduction gear and has provision for installation of Hamilton-Standard constant-speed propeller-governor, which is driven from cam-pinion. Oil passages are cast integral with nose section, thus eliminating external oil lines. Power sections joined by through-bolts and flanges of cylinders. Blower section, bolted to power section, contains supercharger, and lugs for mounting bolts. Accessory section is bolted to blower section and supports all accessories, carburetter-intake elbow. Improved diffuser of increased diameter provides greater efficiency with rearrangement of integrally-cast vanes.

VALVE GEAR.—One inlet and one exhaust valve per cylinder. Exhaust valves are sodium-cooled and have stellite seats. Actuated by ball-bearing rocker-arms and push-rods of heat-treated aluminium-alloy with hardened steel ball-ends. Two shelf-mounted cams, one in front power section and one in rear, are driven by spur reduction gears directly off crankshaft at one-eighth crankshaft speed. Tappets are also mounted in the front and rear power sections. All valve gear, including push-rods, is completely enclosed and oil-tight. Internally-drilled passages for lubrication in both ends of push-rods, in rocker-arms and rocker-bearings.

INDUCTION SYSTEM.—One double Stromberg carburetter from which mixture passes through blades in rear section intake elbow to supercharger, thence through diffuser vanes to annulus in blower section and to intake pipes. A "flat type" hot-spot, consisting of a stainless-steel manifold in an aluminium casting, is mounted between the carburetter and rear section for heating the mixture. The Pratt & Whitney Automatic Mixture and Power Control is available, which automatically controls fuel flow to minimum permissible consumption for any desired power output.

SUPERCHARGER.—Impeller shaft supported by three bearings is in line with crankshaft and is driven from rear crankshaft gear through a floating gear and an outboard bearing gear train. A spring coupling in the crankshaft rear gear is provided to relieve stresses of sudden acceleration and deceleration. Blower ratio 11 : 1.

IGNITION.—Two "Scintilla" SB14RN1A magnetos, each operating an independent set of spark-plugs through separate front and rear manifolds, from which shortest possible leads are provided. Radio-shielding is provided as standard equipment.

LUBRICATION.—Forced lubrication from oil pump through pipes in rear and blower section, thence through oil seal rings into crank-shaft. Cam and cam gear train, impeller gear train, accessory drives, master-rod bearing and knuckle-pins, all lubricated by pressure oil. Cylinder walls, pistons and piston-pins, are lubricated by mist or spray from pressure lubricated parts. For valve gear lubrication, oil is led to a manifold within front main crankcase, thence through drilled tappets and push-rods to valve gear, providing constant pressure lubrication to all valve mechanism. Inter-rocker-box and inter-cylinder drain pipes are provided, from which the return oil is scavenged by a third stage on the oil pump through a separate sump. An automatic oil temperature control is standard.

REDUCTION GEAR.—Planetary type of patented Pratt & Whitney design, comprising a drive gear splined to the crankshaft pinions in a cage splined to the airscrew-shaft, and a fixed gear bolted to the nose section. Available in the ratios of 2 : 3 (.666) or 3 : 4 (.750).

ACCESSORY DRIVES.—Accessories are driven by three lay-shafts, each shaft carrying a spur-gear at its forward end, which engages with a gear attached to the rear of the crankshaft. Upper shaft provides drive for starter and generator. Each of two lower shafts drives one magneto. Two vertical drives for each of these shafts are provided by spur-gears. Upper drives are for gun synchronisers (or accessory pumps) and tachometers. Lower shafts drive oil pump on right and fuel pump on left. Provision is also made for an angle-drive on lower left-hand side for vacuum pump.

MODEL SB4-G.

DIMENSIONS.—Overall diameter 44⅛ in. (1.121 m.), Overall length 53¼ in. (1.353 m.).

WEIGHT—Dry 1,116 lbs. (500 kg.)

PERFORMANCE (C.F.R. 87 octane fuel).—Take off 825 h.p. at 2,625 r.p.m., Normal or maximum climb 750 h.p. at 2,550 r.p.m. at 9,000 ft. (2,745 m.), Cruising 525 h.p. at 2,250 r.p.m. at 14,000 ft. (4,265 m.), Maximum for continuous emergency operation 800 h.p. at 2,550 r.p.m.

THE PRATT & WHITNEY "TWIN-WASP" SERIES "C."

TYPE.—Fourteen-cylinder two-row air-cooled radial.

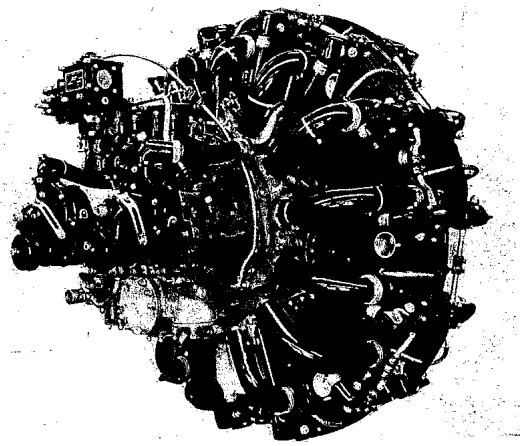
CYLINDERS.—Bore and Stroke 5.50 in. (139.50 m/m.), Capacity 1,830 cub. in. (30 litres). Compression ratio 6.7 : 1. Built up with cast aluminium head, screwed and shrunk onto steel barrel. Head has further refined deep, close-spaced fins, and integrally-cast finned rocker-boxes, providing additional radiating area. Both intake and exhaust ears on all cylinders have cowl-mounting lugs. Longer threads are provided in the spark-plugs for better heat transfer. Exhaust ports have shrunk-in stainless-steel liners providing slip joint with exhaust steel pipes. Nitralloy cylinder-barrels, with integral fins, machined from steel forging, is tapered towards hemispherical combustion chamber, thus compensating for expansion and providing longer life. Aluminium-bronze valve-seats for intake, steel for exhaust, are shrunk into heads. Baffles to provide forced cooling air to entire cylinder in all flight conditions standard.

PISTONS.—Forged aluminium, ribbed on under side of head for strength, have finned inner skirts for additional cooling surface. Three compression rings, one oil scraper ring and one dual oil control ring each.

CONNECTING RODS.—As "Twin Wasp-Junior."

CRANKSHAFT.—Two-throw one-piece type, with increased crank-pin diameter for greater bearing area, supported by three roller-bearings in crankcase sections, and located by the front main bearing. Airscrew-shaft is supported within crankshaft by lead-copper pilot bearing and in nose section by deep-groove ball-bearing which absorbs engine thrust.

CRANKCASE.—In six sections. Power sections machined together from aluminium forgings. Nose section houses reduction gears and has provision for Hamilton-Standard Hydromatic full-feathering, Curtiss electric full-feathering, and Smith controllable airscrews. Governor pad, fed by oil passages cast integral with nose section to eliminate external oil lines, is inclined to provide clearance for



The 1,200 h.p. "Twin-Wasp C" Engine.

latest type governors driven from cam intermediate gear. Power sections joined by through-bolts and flanges of cylinders. Blower section, bolted to power section, contains supercharger and carries bronze-bushed, forged steel, lugs for mounting bolts. Blower intermediate section, bolted to blower section, carries down-draught carburetter and impeller gear train. Accessory section of new design is bolted to blower intermediate section.

VALVE GEAR.—As "Twin Wasp-Junior."

SUPERCHARGER.—Large diameter impeller of improved design, carried by high-capacity ball-bearings is driven by dual intermediate gears containing spring-type flexible drives to absorb shocks and to equalize driving loads. Blower ratio 7.15 : 1.

INDUCTION SYSTEM.—One double barrel down-draught carburetter with manifold-pressure economizer idle-cut-off and self-priming from which mixture passes through blades in intermediate rear section directly to supercharger, then through separate diffuser plate, and enlarged induction passages affording excellent distribution and contributing to improved performance at high levels. Pratt & Whitney Automatic Mixture and Power Control which automatically controls fuel-flow to minimum permissible consumption for any desired power out-put is optional.

IGNITION.—Two "Scintilla" flange-mounted magnetos each operate independent set of spark-plugs through single manifold located on front of engine to simplify maintenance and provide shortest possible leads. Radio shielding is standard.

LUBRICATION.—Forced-feed lubrication by oil pump with separate low-pressure system to accessory drives in rear-section regulated by independent low-pressure relief-valve. Inter-rocker box and inter-cylinder drain-pipes drain to separate sump from which the return oil is scavenged by pump located in nose.

REDUCTION GEAR.—.666 ratio spur-gear, planetary type of Pratt & Whitney design. Alternative ratios of .500 or .5625 are available for use when larger diameter airscrews may be utilized to advantage.

ACCESSORY DRIVES.—All accessories are grouped in the rear and are driven through an intermediate gear train by a single-drive shaft splined directly to the rear of the crankshaft. Provision is made to drive two gun-synchronizers or auxiliary accessory pumps, two magnetos, two tachometers, vacuum pump, oil pump, fuel pump, starter and generator drives. Generator drive may be used as a 30 h.p. take-off to drive a remote accessory gear-box. Pressure lubrication through drilled passages is provided for vacuum pump drive and gun-synchronizer or auxiliary drives.

[64] Compiled and Edited by C G Grey and Leonard Bridgman, Jane's All the World's Aircraft, 1939, Sampson Low, Marston & Company Ltd, p95d-96d.

PRATT & WHITNEY—continued.

THE PRATT & WHITNEY "TWIN-HORNET."

The "Twin Hornet," third and most powerful in the series of twin-row motors developed by Pratt & Whitney Aircraft, is a fourteen-cylinder radial air-cooled type with a displacement of 2,180 cub. ins. (35.72 litres).

CYLINDERS.—Built up with a cast aluminium head screwed and shrunk onto a steel barrel. Head has deep, closely spaced fins, and integrally-cast finned rocker-boxes. Cowl mounting lugs are provided on all rocker-boxgears. Spark plug bushings are provided with long threads for better heat transfer. Exhaust ports have shrunk-in stainless steel liners providing slip joint with exhaust pipes. Nitralloy cylinders with integral fins machined with steel forgings are tapered towards hemispherical combustion chamber, thus compensating for expansion and providing longer life. Aluminium-bronze valve-seat inserts for intake, steel for exhaust, are shrunk into head. Pressure baffles providing forced cooling air to entire cylinder under all flight conditions are provided as standard equipment.

PISTONS.—Forged aluminium, ribbed on underside of head for strength, having finned inner skirts for additional cooling surface, three compression rings, one oil scraper and one dual oil control ring each.

CONNECTING RODS.—Master-rod and connecting rods are as in single-row engines.

CRANKSHAFT.—Two-throw, three-piece, runs in three plain bronze bearings.

*NOTE.—*Dry Weight is with Standard Accessory Equipment and includes Carburetter, complete Radio Shielded Ignition System, Pressure Type Cooling Baffles, Oil Pumps, Propeller Hub Attaching Parts, Priming System and all Standard Accessory Drives.*

PRATT & WHITNEY FOURTEEN-CYLINDER MOTORS

	"TWIN-WASP" SERIES C		"TWIN-HORNET"	"TWIN-WASP JUNIOR"
	SC3-G	S1C3-G	S1A1-G	SB4-G
No. of Cylinders	14	14	14	14
Bore	5.5 in. (139.5 m/m.)	5.5 in. (139.5 m/m.)	5.75 in. (146 m/m.	5.1875 in. (131.8 m/m.)
Stroke	5.5 in. (139.5 m/m.)	5.5 in. (139.5 m/m.)	6.0 in. (152.4 m/m.)	5.1875 in. (131.8 m/m.)
Capacity	1,830 cu. in. (30 litres)	1,830 cu. in. (30 litres)	2,180 cu. in. (35.72 litres)	1,535 cu. in. (25.1 litres)
Compression Ratio	6.7/1	6.7/1	6.66/1	6.75/1
Rotation	—	—	L.H.	L.H.
Gear Ratio	.666 or .500 or .5625	.666 or .500 or .5625	.500 or .5625	.666 or .750
Diameter	48 in. (1,218 m/m.)	48 in. (1,218 m/m.)	51.63 in. (1,310 m/m.	44½ in. (1,121 m/m.)
Length	59.75 in. (1,516 m/m.)	59.25 in. (1,505 m/m.)	64.31 in. (1,631 m/m.)	53¼ in. (1,353 m/m.)
Weight	1,420 lb.(645 kg.) for .666 gear 1,440 lb.(654 kg.) for .500 gear 1,450 lb.(658kg.) for .5625 gear		1,647 lb. (747 kg.)	1,120 lb. (508 kg.)
Take-off Power	1,050 h.p. at 2,700 r.p.m.	1,200 h.p. at 2,700 r.p.m.	1,400 h.p. at 2,500 r.p.m.	825 h.p. at 2,675 r.p.m.
International Rating	900 h.p. at 2,550 r.p.m. at 12,000 ft. (3,660 m.)	1,050 h.p. at 2,550 r.p.m. at 7,500 ft. (2,285 m.)	1,150 h.p. at 2,350 r.p.m. at 7,000 ft. (2,135 m.)	750 h.p. at 2,550 r.p.m. at 9,000 ft. (2,745 m.)
Maximum Power	—	—	—	—

RANGER.

RANGER ENGINEERING CORPORATION.

HEAD OFFICE AND WORKS: FARMINGDALE, L.I., N.Y.
President: Sherman M. Fairchild.
Vice-President: Duncan B. Cox.

The Ranger Engineering Corporation directs its entire activity to the development of inverted, in-line, air-cooled aircraft engines of six and twelve cylinders. In this field the company has no domestic competition, except for smaller engines of less than 300 h.p. Concentrated development on a single type has resulted in approved production models of exceptionally low specific weight and small dimensions.

THE RANGER 6-410B-3.

TYPE.—Six-cylinder in-line inverted air-cooled.

CYLINDERS.—Bore 4⅛ in. (104.8 m/m.), Stroke 5⅛ in. (130 m/m.). Capacity 410 cub. in. (6.73 litres). Compression ratio 6.5/1. Heat-treated steel forged machined barrels have integral cooling-fins and mounting-flange. Barrel screwed and shrunk into cylinder-head, which is of heat-treated cast aluminium-alloy. Cylinder-heads provided with ample cooling-fins, spherically machined combustion chamber, and single inlet and exhaust valves. Aluminium-bronze valve-seats and sparking-plug inserts shrunk into place.

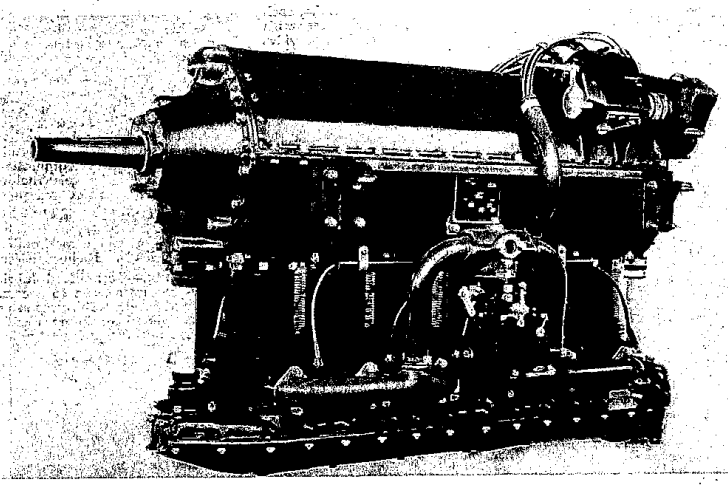
PISTONS.—Trunk type, heat-treated aluminium-alloy, ribbed to provide strength and cooling. Three compression and one scraper rings. Full floating-type gudgeon pins machined from heat-treated nickel-steel held in place by means of spring-steel wire-lock rings.

VALVE GEAR.—Underhead camshaft type, fully lubricated. Completely enclosed by cast-

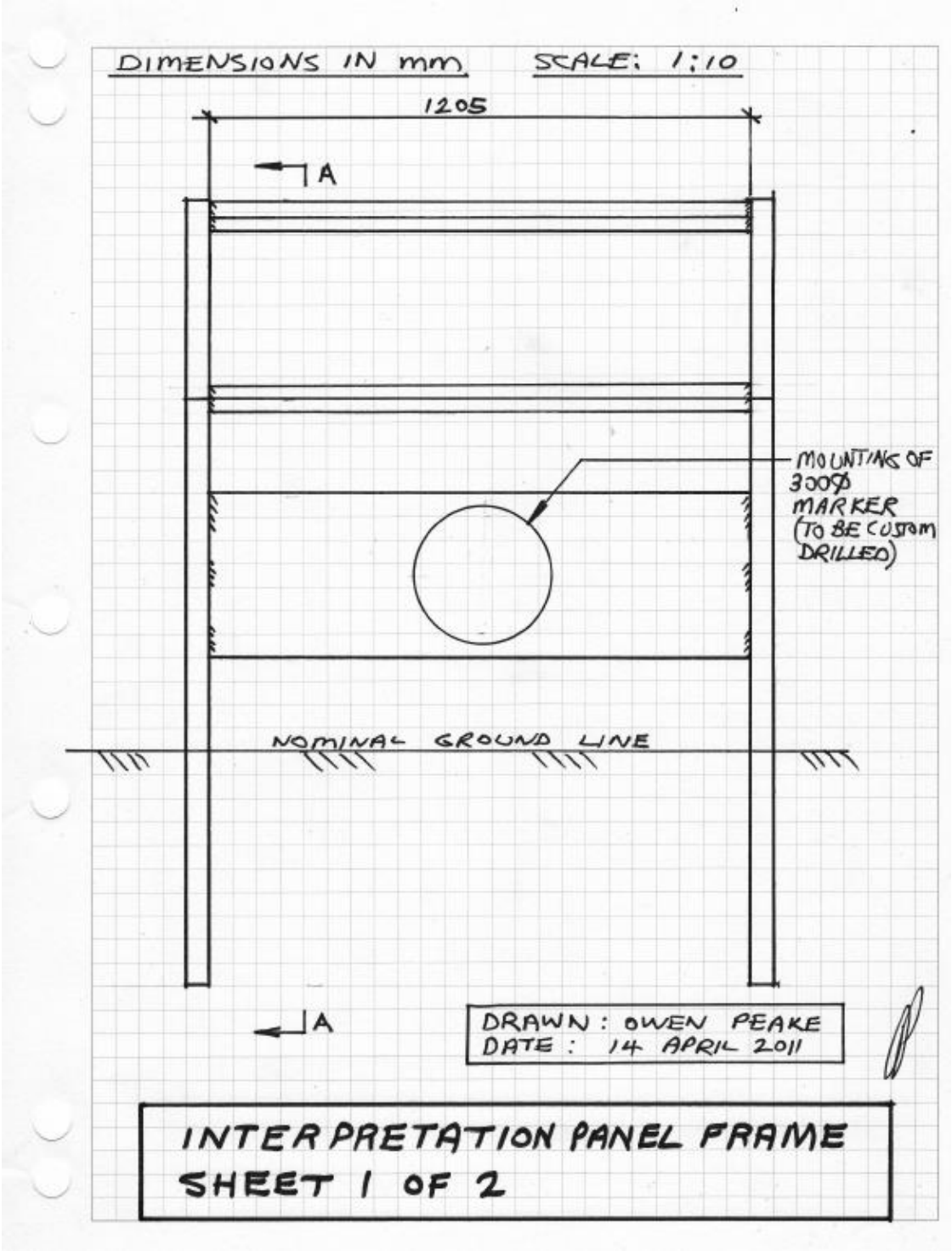
CONNECTING RODS.—Machined from heat-treated chrome-molybdenum steel forgings. "I"-section of shank formed by rolling process.

CRANKSHAFT.—Six-throw seven-bearing type, machined all over, from a heat-treated chrome-nickel steel forging. Main bearing journals and crank-pins drilled for lightness and fitted with oil-retainer plugs, which act as centrifugal oil cleaners.

CRANKCASE.—Semi-elliptic cross-section of heat-treated cast aluminium-alloy. Upper and lower halves parted on centre-line of crankshaft. Upper half carries two long studs at each of the seven main bearings. These extend through lower half-case, act as dowels, and serve to clamp the halves together. Both halves suitably ribbed to ensure stiffness and strength. Lower case provided with four pads for mounting-brackets.



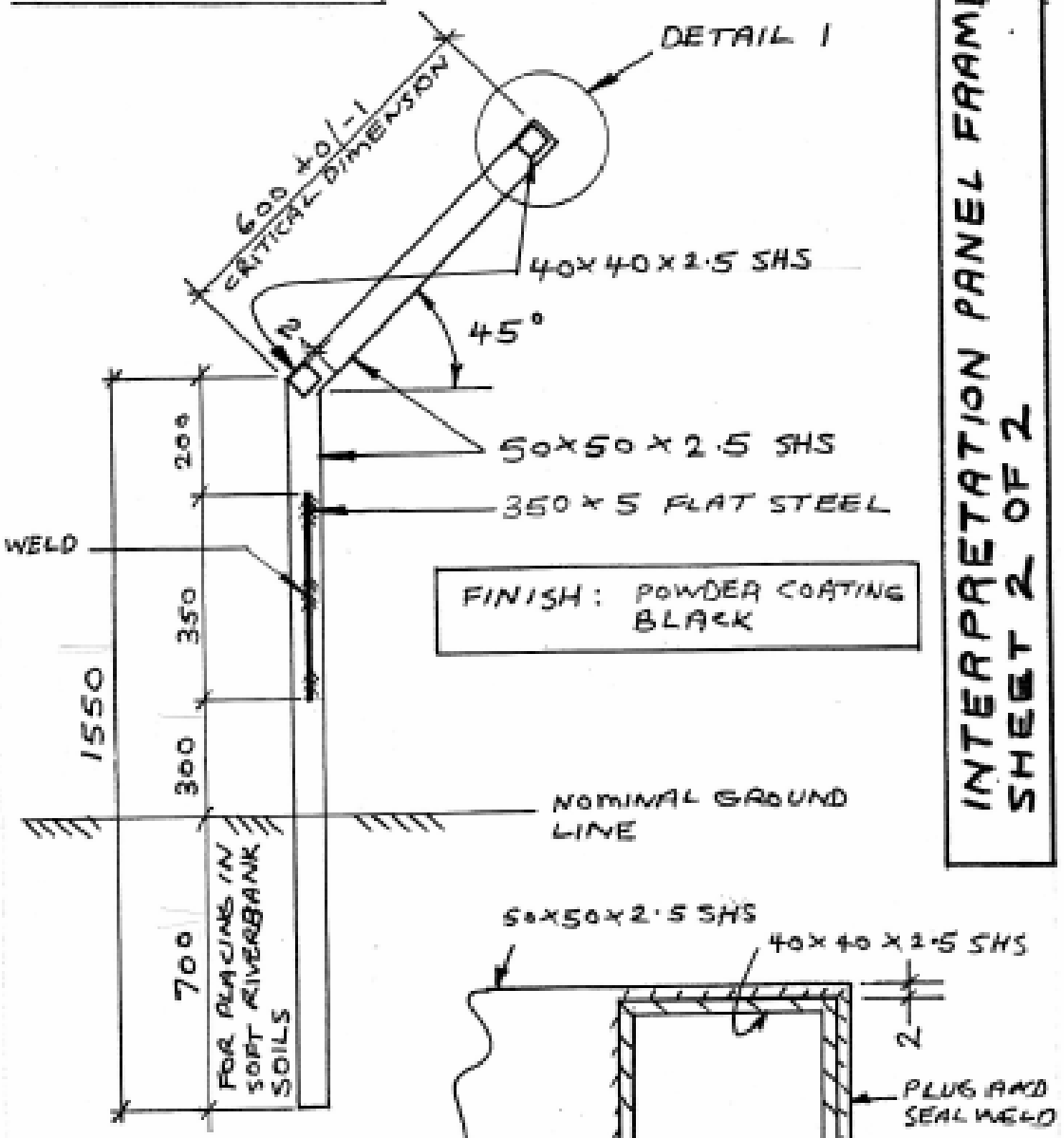
Appendix 4 - Interpretation Panel and Mounting Frame Drawings



FYANSFORD BRIDGE
MELBOURNE TO BENDIGO & ECHUCA RAILWAY

INTERPRETATION PANEL FRAME
SHEET 2 OF 2

DIMENSIONS IN mm



SECTION A-A
SCALE: NOT TO SCALE

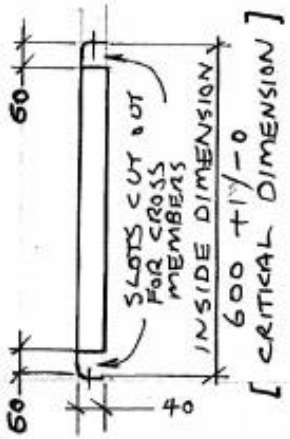
DETAIL 1
SCALE: NOT TO SCALE

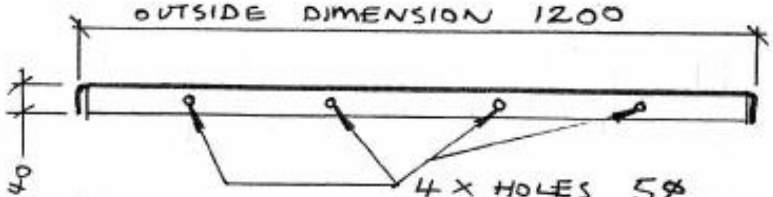
DRAWN: OWEN PEARCE
DATE: 14 APRIL 2011

REVISED
9/9/2012

DIMENSIONS IN mm

SCALE: NOT TO SCALE





NOTES:

1) EDGES FOLDED DOWN ALL ROUND 40 mm
2) TWO PANEL TYPES:
   TYPE A: VITREOUS ENAMEL ON STEEL SCREEN PRINTED
   TYPE B: REFLECTIVE VINYL FILM WITH UV LAMINATE ON ALUMINIUM SHEET

INTERPRETATION PANEL

FYANSFORD BRIDGE - TYPE A
MELBOURNE TO BENDIGO AND ECHUCA RAILWAY - TYPE B

DRAWN: OWEN PEAKE
DATE: 14 APRIL 2011

REVISED 9/9/2012

Appendix 4 – Letter of Approval

Email from Judy Gilbert, Secretary, B-24 Liberator Memorial Restoration Australia Inc.

From: Judy Gilbert judithone@optusnet.com.au
Date: Wednesday, 19 February 2014 3:33 PM
To: owen.peake@bigpond.com
Subject: B-24 LIBERATOR AND WERRIBEE HANGAR HERITAGE RECOGNITION CEREMONY

Hi Owen,

Received your letter re the Heritage Recognition Ceremony. We would be pleased to hold the ceremony at the hangar on 13th July & to help where required. We'll be able to work around the fact that the hangar is open for visitors on Sundays.
We are in the process of spending money we received in a grant to put story boards around the hangar. If possible we would like your interpretation boards to be similar in design so the overall "look" is uniform.
If you like I can send you pictures of our boards so you can check the design/colouring.
Will understand if this is not possible from your point of view.

Regards
Judy Gilbert (Secretary)

CHANGE CONTROL

VERSION 1	**23 JANUARY 2014**		**FIRST DRAFT**
VERSION 2	**24 JANUARY 2014**		**OP FIRST TRACK CHANGES**
VERSION 3	**7 MARCH 2014**		**SECOND DRAFT**
VERSION 4	**9 MARCH 2014**		**OP SECOND TRACK CHANGES**
VERSION 5	**12 MARCH 2014**		**THIRD DRAFT**
VERSION 6	**17 MARCH 2014**		**OP THIRD TRACK CHANGES**
VERSION 7	**25 MARCH 2014**		**FOURTH DRAFCT**
VERSION 8	**16 APRIL 2014**		**FIFTH DRAFT FROM VU GROUP**
VERSION 9	**22 APRIL 2014**		**MINOR EDITING BY OP, ADD COVER IMAGE, ADD INTERP PANEL**
VERSION 10	**24 APRIL 2014**	**12232 WORDS**	**CHECK READ AND MINOR EDIT**
VERSION 11	**8 MAY 2014**	**12233 WORDS**	**ADDED ADDITIONAL ATTRIBUTIONS**
VERSION 12	**20 MAY 2014**	**12276 WORDS**	**PROOF READING ADDED**
VERSION 13	**20 MAY 2014**	**12465 WORD**	**EDITING, ADDED APPENDIX 5**